THE PRINCIPLES OF AGRICULTURE

UNIFORM WITH THIS VOLUME

THE BREEDING AND FEEDING OF FARM STOCK	BY JAMES WILSON
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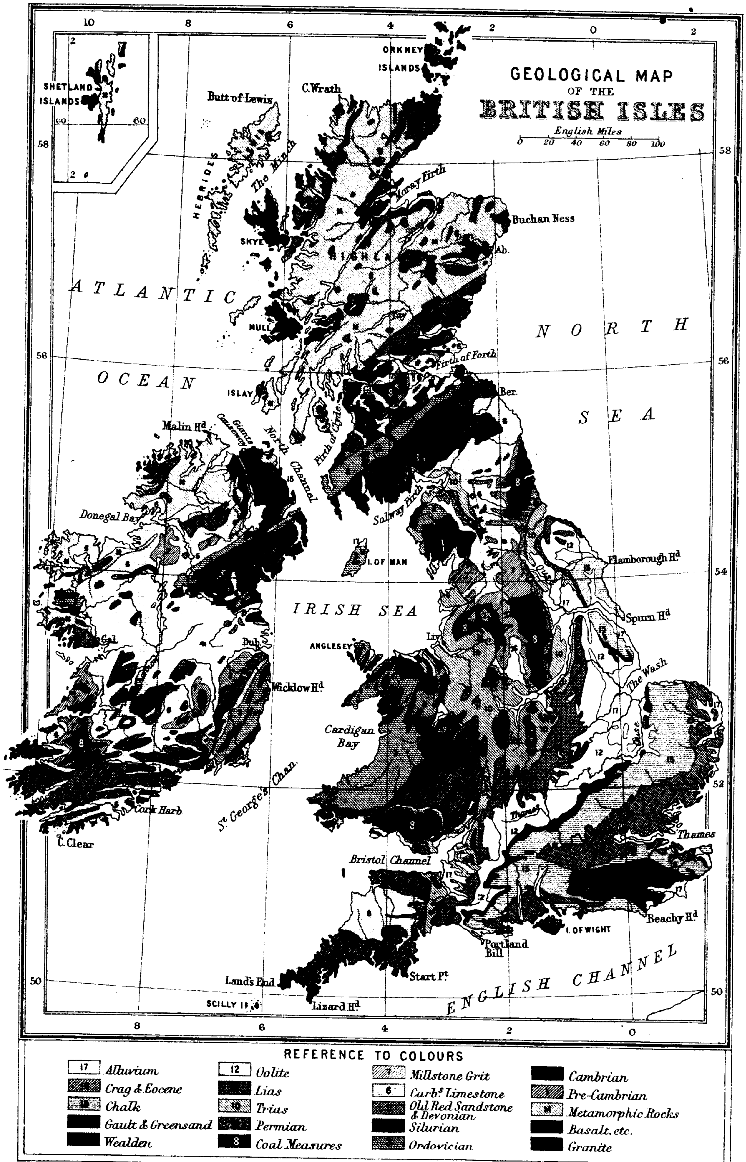

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THE PRINCIPLES OF AGRICULTURE

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PREFACE

THIS book, designed to serve as an introduction to a series written by well-known practical experts in the various branches of Agriculture, endeavours to set forth in simple language the chief facts and scientific principles on which successful practice ultimately depends. It is generally admitted that some knowledge of these is of increasing importance if we are to make the most of the land. The technical terms employed are explained where they first occur, but an index-glossary has been added to make reference easy.

Some account of the structure and life processes of crop plants and farm stock is followed by a review of the plant-kingdom, beginning with the higher types. Weeds, fungoid pests, and bacteria are here included. The botanical section is supplemented by an outline of Geology, with special reference to the origin and nature of soils, and a summary of the principles of manuring. The final chapters deal with the animal kingdom, and give some information regarding both beneficial and injurious forms, and the methods employed in combating the latter.

The courtesy of authors and publishers who have rendered available many of the illustrations is gratefully acknowledged. It is hoped that readers will kindly notify any errors they may discover, and make suggestions for improvement.

May 24, 1923. J. R. AINSWORTH-DAVIS.

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INTRODUCTION

THE farmer is a manufacturer, whose business it is to produce crops and stock, primarily for the purpose of maintaining the nation's food supply, but also for other scarcely less important purposes, such as the provision of wool for cloth-making, hides for conversion into leather, and so forth. He buys or pays rent for land in order to secure a supply of his chief raw material, which is the plant food in the soil, consisting of water with dissolved mineral matter. The soil or earth is a surface layer, of varying thickness, formed by the breaking down of rocks as a result of the action of air, water, and other agencies. The supply of plant food in soils has usually to be supplemented by the addition of manure, the kind or kinds employed depending upon various circumstances.

As we shall soon see, the air, or part of it, is another kind of raw material essential for the making of crops, and all would be useless without the light of the sun. Air and light are—at present—free, though in the future some enterprising Chancellor of the Exchequer may attempt to tax either or both. Indeed, a window-tax was once imposed on the community, but it proved so unpopular that it had to be withdrawn.

Crops, including grass, furnish in their turn the chief kind of raw material used in the raising of stock, but the farmer also purchases 'artificial' foods, such as different kinds of 'cake,' consisting of nutritious substances in a highly concentrated form, and mostly though not entirely of vegetable nature. The raw materials used in raising stock also include water, and various mineral substances. Much of the former, and most of the latter, are contained

in the solid food, but a constant supply of pure drinking water is essential, and some kinds of mineral matter, e.g. salt, need to be provided as such.

The raising of crops and stock so as to secure a reasonable profit is an exceedingly complicated and difficult business, especially as one important factor—the weather—cannot be controlled, and no man can be a thoroughly competent practical farmer and at the same time a scientific expert. Yet the resources of science must be made use of if the utmost possible is to be got out of the land, and the farmer should possess a general acquaintance with the chief scientific principles on which agriculture depends, so that he may know when it is essential or desirable to seek expert advice. Otherwise he is at the mercy of manure merchants, vendors of artificial feeding stuffs, and others who make a living out of the farming community.

Fortunately, in this country, expert advice of all kinds is easily attainable at reasonable charges, or sometimes at only a nominal one, as in the case of the excellent leaflets on a great variety of topics issued by the Ministry of Agriculture. Practically every county has now an organization for solving the farmer's difficulties; the chief Agricultural Societies place expert advice at the disposal of their members; and centres of agricultural education, such as Colleges and Farm Institutes, are always ready to give assistance.

Agriculture is essentially a business, and as such should be conducted on business principles. From this point of view Farm Book-keeping is the most important agricultural subject, while much may be expected by an extension of the co-operative methods which have done so much for Ireland and such foreign countries as Denmark.

THE PRINCIPLES OF AGRICULTURE

CHAPTER I

THE SEED PLANT—MAINTENANCE OF THE LIFE OF THE INDIVIDUAL

THE first duty of the farmer is to raise Crops, consisting of various green plants, from the soil, manure, and air at his disposal. If we have to build a house or make a machine we must first enquire of what materials houses and machines are constructed. The same rule applies to crops, for to grow these successfully we ought to know something about their constituents. This knowledge can be acquired by chemical analysis, or pulling to pieces, a kind of dissection. As the result of such study we find that every plant consists, chemically, of compounds built up from certain chemical elements, i.e. substances that have not so far been broken down into simpler things. Iron and sulphur are common examples of elements.

Plants obviously contain a large amount of **water,** which can be driven off by heat, and as water (OH_2) is a compound of the gaseous elements **oxygen** and **hydrogen** it is clear that these must both be present in plant food. Application of more intense heat results in blackening and burning, proving the presence of the element **carbon**; while appropriate tests at this stage show that a fourth element, the gas **nitrogen,** is another component. When everything else is burnt away, a small proportion of **ash**

remains, consisting of compounds of the two non-metallic elements **sulphur** and **phosphorus,** together with compounds of five metallic elements—**potassium, sodium, calcium, magnesium,** and **iron.**

There are thus eleven elements always to be found on analysis, and the substance of the plant is built up of various compounds formed by the union of these. There are certain to be other elements as well, but it cannot be said that they are essential to life, though some such may be useful, for example **silicon,** which in combination with oxygen makes up the silica (flint) that imparts stiffness to the stems of grasses and cereals. **Chlorine** appears to be essential to buckwheat, and possibly to peas and oats.

PARTS OF A SEED PLANT.—It is a matter of common knowledge that an ordinary tree, shrub, or herb consists of an underground branching **root** and an overground branching **stem** bearing **leaves.** These are so placed and constructed as to take in raw food materials, and afterwards to build them up, step by step, into living plant substance (protoplasm).

THE ROOT

Reacting positively to gravity, and negatively to light, the main root grows vertically and its branches obliquely down into their province, the soil, anchoring the plant firmly, and shortening from time to time to pull it taut. The delicate root-tips are covered by thimble-like **root-caps,** and are thus protected from abrasion by the hard particles of the soil among which they are perpetually feeling their way as elongation takes place. The young ends of the roots, and the innumerable little **root-hairs** by which they are covered a little way behind the growing tips, collectively possess a very large surface through which they absorb liquid plant food from the soil. This food is water, holding in very dilute solution small quantities of simple mineral compounds, containing all the essential elements (see above) except carbon. Which elements *are* essential can be

experimentally determined by 'water cultures,' where plants are grown in distilled water to which various soluble mineral substances are added. It is found, for example, that without compounds of nitrogen, phosphorus, and potassium, growth is impossible, and the same is true for sulphur, calcium, magnesium, and iron. The water itself supplies the necessary hydrogen and part of the necessary oxygen. The same facts can be verified by 'pot cultures,' where sterilized sand is kept moist with water in which are dissolved the chemical compounds used in water cultures.[1]

How Plant Food gets into the Root.—There are no holes in roots for the admission of liquid food, as once supposed, but this makes its way through the delicate moist membranes, covering the root-hairs. Without an advanced knowledge of physics it is impossible to understand how and why liquids pass through membranes of different kind, so we must content ourselves with noticing some simple facts. A piece of parchment tubing is filled with sugar solution, its ends tied up, and then immersed in water. Very soon the tube will swell up and become tense by the passage of water through the parchment into the sugar solution. This passage of water through a membrane is technically known as **osmosis**. Precisely the same thing happens in the case of a root-hair. The sap in the root-hair corresponds to the sugar solution, the water in the soil to the water surrounding the parchment tube, and the delicate elastic covering of the hair to the parchment wall of the tube. Water passes into the hair by osmosis, causing it to swell up and become tense or **turgid,** the elasticity of the delicate investing membrane rendering such increase in volume possible.

We have further to realize that many substances in

[1] A complete food solution can be made by dissolving the following in a litre of distilled water :—

Calcium nitrate	1·0 gram
Potassium chloride	0·25 ,,
Magnesium sulphate	0·25 ,,
Potassium phosphate	0·25 ,,
Ferric chloride	trace

solution, including gases, are able to pass through moist membranes, and to this process we can apply the term **filtration.** In this way the simple mineral salts dissolved in the water of the soil get into the root-hair, and, on the other hand, some of the substances dissolved in the sap of the root-hair are able to pass out into the soil. But this outward filtration is of less amount than the inward filtration. For when two solutions of different strength are separated by a moist membrane there will be more filtration into the denser solution than out of it.

Root Structure.—Like all parts of a higher plant (or animal) the root is made up of an immense number of minute parts—**cells**—and the products of their activity. During the latter part of the seventeenth century, when the microscope was in process of evolution and the Royal Society had recently been founded, certain observers cut thin slices or sections through dried plant parts and found that some of these were apparently made up of six-sided air-containing compartments, having some resemblance to the cells of a honey-comb. These structural elements were consequently named 'cells.' During the first half of last century, by which time the microscope had been immensely improved and great advances made in the methods of preparing objects for examination, it was found that such cells were not empty—except in certain cases—but contained a slimy substance, and this was named **protoplasm,** afterwards called by Huxley 'the physical basis of life.' The next advance was the discovery of a specialized particle or **nucleus** within the protoplasm, and this has since been shown to be the centre of the cell's activity, and to be exceedingly complex in structure.

A typical mature plant cell consists of the parts just mentioned (Fig. 1), but a few details may be added with advantage. The thin elastic cell-wall is made of **cellulose,** a substance allied to sugar and starch.[1] Within it is the

[1] Cellulose, sugar, and starch, are examples of **carbohydrates,** which are composed of carbon, oxygen, and hydrogen; the two latter being in the same proportion as in water, i.e. two atoms of hydrogen to every atom of oxygen.

living **protoplasm,** which is of extremely complex chemical composition, and probably a mixture of various compounds, the most important being the nitrogenous substances known as **proteins,** of which more will be said elsewhere. The protoplasm is divided into (*a*) cytoplasm and (*b*)

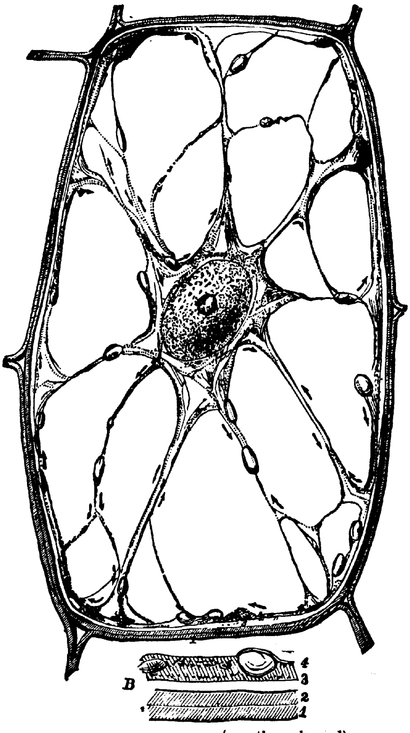


FIG. I. PLANT CELL (greatly enlarged)

A. A typical living cell, with central nucleus and nucleolus; the clear spaces are vacuoles full of cell-sap. The arrows show the direction of currents in the cytoplasm. B. Part of cell-wall and cytoplasm, still further enlarged: 1 and 2, common cell-wall of two adjacent cells; 3 and 4, layers of cytoplasm, the latter with two chloroplasts.

nucleus. The **cytoplasm** commonly forms a sort of lining to the cell-wall, surrounding a central space or **vacuole** filled with slightly acid **cell-sap,** which also permeates the

protoplasm and cell-wall. The **nucleus** is imbedded in the cytoplasm, and often contains a particle of different nature known as the **nucleolus.** When cells are subjected to the action of certain dyes, such as haematoxylin (extract of logwood), the nucleus stains more deeply than the

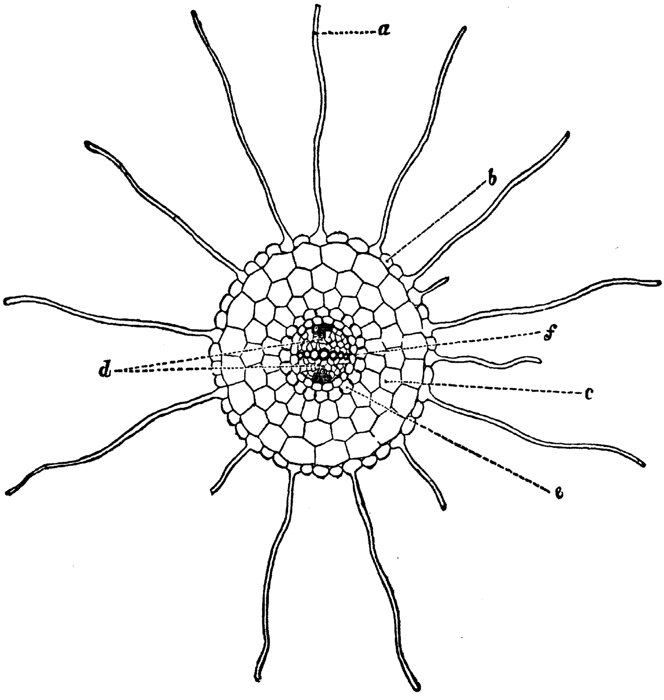


FIG. 2. UNTHICKENED ROOT (enlarged)

Transverse section of root of Cress (*Lepidium sativum*): *a*, root-hair; *b*, piliferous layer; *c*, cortex; *d*, strands of bast above and below; *f*, two strands of wood united in centre (outside them is the pericycle made up of one layer of cells); *e*, endodermis (innermost layer of cortex).

cytoplasm, owing to the presence of a network of specialized protoplasm (chromatin) which has a special affinity for the colouring matter.

Root Structure (Fig. 2).—The outer part of a young root

is covered by a layer of flat cells, and these are drawn out into finger-like root-hairs over a region a little way from the tip. This external layer is consequently known as the hair-bearing or **piliferous layer.**

Within this skin-like investment we find a **cortex,** made up of several layers of thin-walled cells, and inside this again is a central **vascular cylinder** or **stele,** largely consisting of microscopic tubes (vessels) in alternate groups of **bast** (phloem) and **wood** (xylem). The tubular elements of the former are **bast vessels** (sieve tubes) with soft cellulose walls and slimy protoplasmic contents. Each of them is developed from a longitudinal row of elongated cells, the cross-walls between which are perforated like the top of a pepper-pot. Threads of cytoplasm pass through these holes, so that the contents of a sieve-tube are continuous. The tubular elements of the wood are **wood-vessels** with thickened walls of woody substance, chemically allied to cellulose. Such a vessel is formed by the fusion of a longitudinal row of elongated cells, with absorption of the cross-walls between them and disappearance of the protoplasm. It is in fact a tube constructed from a string of dead cells. The walls of these vessels are not thickened everywhere, for thin places are left through which liquid can filter. The thickening may take the form of a spiral (spiral vessels), or of successive rings (annular vessels), but more frequently there are thin places of rounded or elongated form, known as 'pits' (pitted vessels).

The vascular cylinder also contains **fibres,** dead spindle-shaped cells with woody walls, and small thin-walled living cells. Some of the latter make up a layer (pericycle) external to wood and bast, and outside this again is a layer of flattened cells (endodermis), which may be regarded as a sort of sheath and really belongs to the cortex.

Plant food passes from the root-hairs through the successive layers of the cortex, the pericycle, and the endodermis, to the wood-vessels, and is filtered under pressure through the thin parts of these to be conducted upwards.

This upward current of **crude sap**, the very dilute watery solution of mineral substances absorbed from the soil, travels through the wood-vessels of root, stem, and leaf, to serve as part of the raw material (the other part being carbon dioxide from the air) that is worked up by the living green tissue of the leaf (and young stem) into organic substances of much more complex nature, as explained later on. These substances are then dissolved to form **elaborated sap,** which is carried away in a downward current, for which the sieve-tubes of the bast furnish the most important path.

The course of the upward current can be demonstrated by placing a broad bean seedling with its root in red ink, when after a time the strands of wood in root, stem, and leaves, will be stained red. The means by which this conduction is effected are not fully understood, but the active absorption of liquid from the soil sets up what is called **root pressure,** by which the ascent of sap is aided. This is most active in spring, at which time it can be demonstrated by cutting across the stem of a plant, when sap oozes out continually, i.e. the plant 'bleeds.'

The vascular cylinder, in virtue of its thick-walled elements, also performs an important **supporting function,** acting like the steel core to a rope, and resisting pulling stresses, which it is essential an anchoring arrangement should be able to do. Deeply seated roots are more effective than those which keep nearer the surface: hence the contrast between the firmly fixed oak and the easily overturned elm.

A root **increases in length** by active division of a group of small thin-walled cells at its tip, which make up the 'growing point,' this being protected from injury by the root-cap. There is thus a continual boring through the soil in search of plant food.

Careful examination will show that the branches of a root are arranged in a varying number of longitudinal rows, and it will also be found that each branch emerges from a sort of slit or cleft. Cross sections reveal the

meaning of this. They show that a branch root takes origin in the pericycle, outside one of the groups of woody tissue, thence pushing its way to the exterior, secure from injury until the soil is reached. The number of groups of woody tissue varies in different plants, and this determines the number of longitudinal rows of root-branches. In cress, for example, there are two such groups and two rows of root-branches; while there are four of each in the broad bean.

It is only the young parts of roots that absorb plant food from the soil. In plants that live for two or more years the older parts **increase in thickness,** and are thus better able to carry out the work of conduction and support. This thickening is brought about in a way which will be subsequently described in dealing with the stem.

THE SOIL.—Increasing attention is being paid to investigations on the soil. This 'subterranean pasture,' as Jethro Tull styled it, is of extreme complexity, and presents a great variety of problems which are only partially solved. It is produced by the crumbling down of rocks, this being brought about by the action of various agencies, including air, rain, frost, organisms, and so forth. A soil is called **sedentary** when formed in the place where it is now situated, and **transported** if brought from elsewhere, as in the case of alluvium carried down by a river in flood and deposited on the adjacent land. Lower Egypt, for example, is made up of alluvium borne by the Nile, while the level fertile meadows bordering many British rivers are composed of similar material.

The worn particles of soil do not fit closely together into a continuous mass, but there are minute crevices between them, collectively constituting the **pore space** (Fig. 3). The water circulating in these is termed **free water,** because it drains away more or less readily, to make room for air, which is essential for the life of the roots—since these—like all living parts of a plant (or animal)—**breathe** or **respire,** i.e. they absorb *free oxygen* from the air and

give off the waste product *carbonic acid gas* or *carbon dioxide* (CO_2), which is dissolved in the sap that is continually oozing outwards. It is true that swamp plants manage to live in water-logged soil, but the farmer's crops cannot thrive unless air circulates freely round their roots. Below a certain level the pore space of the soil is completely filled with water, and the object of **drainage** is to bring this level (the 'water table') below the roots, so that they can breathe. Free water moves with difficulty through

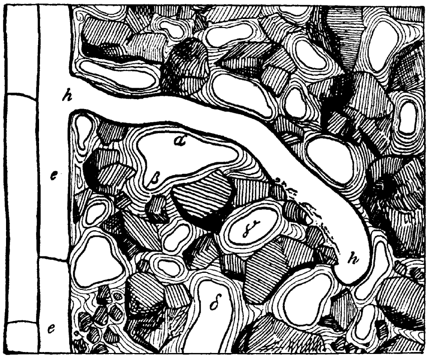


FIG. 3. STRUCTURE OF SOIL (enlarged and diagrammatic)

ee, External cells of a root, from one of which a root-hair (*hh*) is growing out. The particles of soil are darkly shaded, the films of hygroscopic water are indicated by concentric lines, and the air-spaces are left white.

heavy soils, containing a large amount of clay, and drainage operations are particularly necessary in the case of such soils, and especially difficult to effect. The movement of the free water can be facilitated, however, by indirect means, as by the addition of bulky manures—such as farm-yard manure—which improve the texture of the soil by opening it out, so as to enable air to get in and water to drain away. A more potent method of loosening clay and the like is **winter ploughing,** whereby clods are subjected to the action of frost, with the result that the water in their pore space freezes, expands, and causes

them to crumble down, providing a suitable 'tilth' in which seeds can germinate with advantage.

PLANT FOOD IN THE SOIL.—The roots of a plant do not absorb the free water of the soil as food, but rely upon that which does not circulate in the pore space but adheres in thin films to the soil particles. If a seedling is carefully pulled out of the ground, many of these particles will be found clinging to the root-hairs, with which they come into intimate contact. The breaking up of the soil by ploughing and other acts of tillage is important not only for promoting the circulation of air and water, but also because it increases the surface to which films of water adhere, thus giving a larger area over which the roots can feed. A moment's thought will make this clear. Let an apple represent an enormously enlarged particle of soil. Cut it in half, and the collective surfaces of the two pieces will be that of the undivided fruit plus the area of the two cut surfaces.[1]

As already mentioned (p. 2), certain elements, contained in simple mineral compounds, and the water in which they are dissolved, are essential components of plant food. When existing in the soil in this soluble form such mineral substances constitute **available plant food,** because roots can absorb them. But a large amount of these substances is present in an insoluble form and may be called **unavailable plant food.** A chemical analysis of soil which does not give some idea as to what is soluble and what is not may prove distinctly misleading.

The surface of the soil particles is continually subjected to the chemical action of circulating air and water, the result being that fresh supplies of available plant food are constantly being produced from the unavailable. Tillage, by breaking up the soil, promotes the circulation of air and water and increases the surface over which these can

'[1] As a rough figure to remember, the surface of the particles in one cubic foot of an ordinary light loam may be taken as about an acre; this will increase as the soil approaches more and more to clay, and diminish as the soils becomes increasingly sandy.'—(Hall, *The Soil*, pp. 66–7.)

act. It is therefore in itself a kind of manuring. In fact the word ' manure ' originally meant ' to till or cultivate,'' and we find it used in that sense in *Robinson Crusoe*.

MANURE.—This term is now applied to a great variety of substances which are added to a soil on which excessive demands are made, or which is naturally lacking in one or more essential kinds of plant food. Up to the end of the eighteenth century farmers relied almost entirely for this purpose on the droppings of grazing stock in the case of grass land, and the same material mixed with straw and other kinds of litter (**farm-yard manure** or **dung**) for the enrichment of arable. Even at the present day the proper conservation and use of farm-yard manure is of primary importance, since it contains all the requisite kinds of plant food, and also improves the texture of the soil (p. 10).

We now use a large number of other manures, many being known as **artificials,** which are of comparatively small bulk, and receive their name from the fact that they usually result from special manufacturing processes. The chief among such manures contain potassium, phosphorus, or nitrogen, and the last at the present moment are of particular interest. For many years the chief nitrogenous mineral manure has been **sodium nitrate** or Chili saltpetre (N_2NO_3), and this has been mainly obtained from arid tracts on the west side of S. America. The supply is not inexhaustible and has been greatly depleted, so that some substitute is now desirable and later on will be essential. The solution of this problem depends on the fact that air is mainly composed of free nitrogen. It is possible, by electrical means, to cause this free nitrogen to enter into combination, with formation of the important new manures **calcium nitrate** and **calcium cyanamide** (nitrolime). For the generation of the necessary electricity water power is used, as at Odde in Norway.

It is interesting to note that the living root itself helps in the preparation of plant food. For a certain amount of sap diffuses out of its thin outer cells into the soil, and

being rendered acid by the carbon dioxide resulting from breathing helps to dissolve the mineral matters there present. All living parts of the plants breathe or respire, taking in oxygen and giving out carbon dioxide as a waste product (see p. 23).

HUMUS.—Soil is distinguished from the underlying subsoil not only by its finer state of division, but also by the presence of **humus,** a dark substance of great complexity and varying composition which results from the decay of vegetable and animal matter. When present in reasonable amount it improves the texture of the soil, and it is the seat of chemical processes associated with the presence of microscopic organisms, and which will be dealt with in a later chapter.

STORAGE BY THE ROOT.—We have already seen that the root fixes the plant in the soil, absorbs plant food, and breathes. It may also serve as a receptacle for the storage of certain 'reserve materials,' which have been formed within the plant for future use. In such cases the root is swollen, as exemplified by turnip, carrot, mangel, radish, and parsnip.[1] **Starch** is the most typical reserve material, but **sugar** is not uncommon, a particularly good example being found in sugar beet. Plants with roots so thickened are usually **biennials,** i.e. they live for two years, during the first of which reserve materials are stored in the root, these materials being used up during the second year in the formation of flowers and fruit.

THE STEM

That part of a typical green plant which lives above the soil is termed the **Shoot,** consisting of Stems and Leaves. The **primary stem** or axis of the main shoot behaves in exactly the opposite way to the primary root with regard to light and gravity, reacting positively to the former and negatively to the latter. Hence it grows

[1] The uppermost part of such a 'root' is usually the thickened base of the stem.

vertically upwards and its branches obliquely upwards, bearing the flat expansions known as **Leaves,** whose work is done in the air and light.

The leaf-bearing regions of the stem are known as **nodes,** the intervening parts as **internodes.** At its tip there is, as in a root, a growing point, and here young

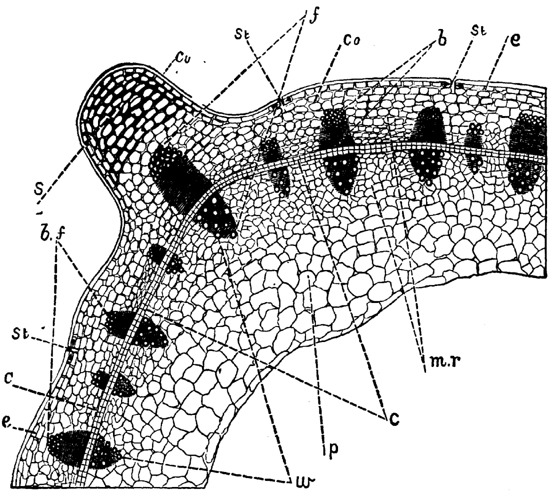


FIG. 4. UNTHICKENED STEM OF DICOTYLEDON (enlarged)

Transverse section of corner of a Broad Bean stem (*Vicia faba*): *e*, epidermis; *cu*, cuticle of ditto; *co*, cortex; *m. r.*, primary medullary ray; *p*, pith, part of which has disappeared from the centre of the hollow stem; *f*, vascular bundle; *b*, bast; *b. f.*. bast fibres (the shaded part between these and the cambium represents bast-vessels and parenchyma); *c*, cambium; *w*, wood; *s*, strengthening cells at the corner; *st*, stoma.

leaves are being formed, but as the internodes in this region have not yet elongated these young leaves are crowded together into a **terminal bud.** The delicate growing point is thus protected efficiently, and there is nothing corresponding to a root-cap. Other buds develop

in the **axils** of the leaves, i.e. the upper angles between them and the stem, and these grow into secondary shoots, on which others may arise in the same way, and so on, until a system of branches is formed. The arrangement of such a system varies in different species, but in any case it is a device for displaying leaves, flowers, and fruits to the best advantage. As the branches grow obliquely upwards they do not interfere with the main stem.

It is necessary at this point to distinguish between **Dicotyledons** and **Monocotyledons,** the two great groups of Seed Plants to which crops belong. If seedlings of mustard and cress are examined it will be noted that they start life with one pair of leaves, differing in shape from their successors, and known as **seed-leaves** (because already present in the seed) or **cotyledons.** This is true for most crop-plants, but in grasses and cereals there is only one seed-leaf or cotyledon. This is the primary distinction between Dicotyledons and Monocotyledons, as the names indicate (Gr. *dis*, double; *monos*, single). We also find that in Dicotyledons the veins of the leaves are arranged in a complicated network, while in Monocotyledons the main veins are more or less parallel.

Structure of Stem (Fig. 4).—The young stem of a Dicotyledon resembles a young root in structure to a certain extent. There is an external layer of flat cells, here known as the **epidermis,** which often bears hairs, and within which are **cortex** and **stele**, as in the young root, but the wood and bast are not arranged in alternating masses. Instead of this we find a ring of **vascular bundles** or strands, each with bast externally, wood internally, and between the two a thin layer of very delicate cells, the **cambium**, by which thickening is brought about in plants which have a prolonged life (Fig. 5). A vascular bundle capable of growth owing to the possession of cambium is said to be 'open.' Bast and wood consist of vessels and other elements, as in the root (p. 7), and there may be fibres in the pericycle. There is also a central **pith,** connected by radial strips of tissue, the **medullary rays,** with

the cortex. The disposition of the bundles in a ring enables effective resistance to bending movements caused by the wind, especially as they are connected by cross-branches at the nodes.

The stem of a typical Monocotyledon, such as a grass, differs from the preceding in several ways, especially as regards the distribution of the vascular bundles. As seen in a cross section these are numerous and scattered, not arranged in a ring. They are 'closed,' i.e. possessing no cambium, so that as a rule there is no increase in thickness of a fully formed stem, or when there is it is brought about in a different fashion.

Storage by the Stems.—The stem is often of importance in the storage of reserve materials, and presents a variety

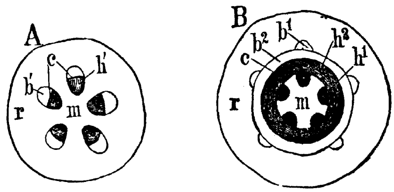


FIG. 5. THICKENING OF STEM

Diagrammatic transverse sections of normal stem of a Dicotyledon: A. Very young, with five isolated bundles; *m*, pith; *r*, cortex; b^1, primary bast; h^1, primary wood; *c*, cambium. B. After growth in thickness has commenced: b^2, secondary bast; h^2, secondary wood.

of devices for this purpose. There may be a swelling at the base of the stem, just above ground, as in kohlrabi, a relative of the cabbage; but in most cases storing stems are underground altogether. It is a mistake to suppose that plant parts below the surface of the soil are necessarily roots, though they are so termed in agricultural language, and a 'root' crop is simply one in which the parts harvested have to be dug up.

The most familiar agricultural example of a thickened underground stem is the **tuber** of the potato, which is in reality a swollen branch. Its 'eyes' are buds, borne in the axils of scale leaves. The stored reserve material is mostly in the form of starch, but a small part of it is

nitrogenous, and this is to be found in the cells immediately under the corky rind, so that when a potato is peeled in the ordinary way its most nutritious part is removed.

THE LEAF

Having briefly considered the stem part of the shoot we now come to the **Leaf,** which is the most important part of an ordinary plant. There are leaves of widely different kind, such as foliage leaves, scale leaves, bracts and flower leaves. The first kind are so called because they make up the 'foliage' or conspicuously green part

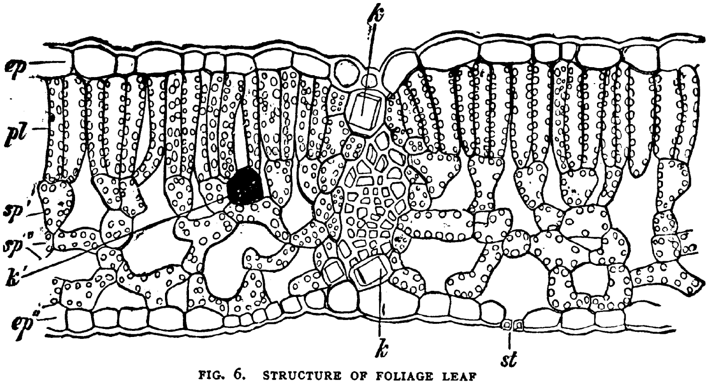


FIG. 6. STRUCTURE OF FOLIAGE LEAF

Transverse section of leaf of Beech (*Fagus sylvatica*), enlarged : *ep*, upper epidermis ; *ep''*, lower epidermis, with a stoma (*st*) ; *pl*, palisade layer ; *sp*, spongy parenchyma, with large intercellular spaces (the small circles in the cells of *pl* and *sp* represent chloroplasts) ; *kk*, cells containing simple crystals, and *k'*, cell containing a cluster crystal of oxalate of lime. A vascular bundle (vein) is seen between *k* and *k*.

of a herb, shrub, or tree. A typical **Foliage Leaf** is a flat structure growing from a node of the stem, possessing or devoid of a stalk and varying greatly in shape according to the species or kind of plant. The shape and arrangement of leaves—in average cases—are such as to expose as large a surface as possible to air and light. Inspection of the foliage of beech, horse-chestnut, sycamore and so forth, will show that sunlight falls directly on a very large percentage of the total leaf surface, individual leaves

shading others to a much smaller extent than might have been anticipated. One flat surface of each leaf faces more or less upwards.

Structure of the Foliage Leaf (Fig. 6).—By holding a thin leaf up to the light it will be easy to see a complicated arrangement of larger and smaller 'veins' which are still more obvious in the 'skeleton leaves' resulting from partial decay. These veins are the **vascular bundles**, continuous with those of the stem and serving the same two purposes, i.e. support and conduction of sap. They are imbedded in the soft green tissue that forms the middle layer of the leaf and is known as **mesophyll.** This is covered by flat-celled **epidermis** both above and below.

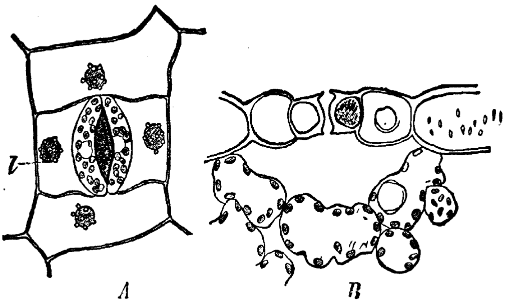


FIG. 7. STOMATA (x 240)

A. Bit of lower epidermis of Spider-wort (*Tradescantia virginica*) leaf, showing a stoma in surface view: l, starch-forming bodies (amyloplasts) in cells adjoining stoma. B. Stoma in section, with large air-chamber and a few cells of the spongy parenchyma.

The mesophyll is divided into two regions, one of elongated closely packed **palisade cells** beneath the upper epidermis, and the other of irregular cells adjoining the lower epidermis and forming a 'spongy' layer traversed by numerous air-spaces. These spaces are in direct communication with the exterior by numerous microscopic holes (*stomata*) in the lower epidermis, while a smaller number may also be present in the upper epidermis. A **stoma** (Fig. 7) is bounded by two kidney-shaped **guard-cells,** which alter in shape according to circum-

stances, regulating the size of the opening, and sometimes closing it.

It is particularly noteworthy that the cells of the mesophyll, and also the guard-cells of the stomata, contain microscopic particles of a green colour, **chloroplasts**, which are in reality specialized portions of protoplasm permeated by the pigment leaf-green or **chlorophyll**, an extremely complex compound.

WORK OF THE FOLIAGE LEAF.—This includes feeding, breathing (respiration), and the giving off of water vapour into the air (transpiration). With regard to **feeding** the foliage leaf takes in carbon dioxide (CO_2), which makes up about ·04 per cent (by volume) of air, as a raw material, and effects what is commonly termed 'carbon assimilation.'[1] This takes place in the green cells, especially those of the palisade layer, and essentially consists of a reaction between carbon dioxide and water (absorbed by the root), whereby organic substance is built up and free oxygen liberated. This probably takes place in two stages.—

1. (*a*) Splitting of carbon dioxide
   $CO_2 = CO$ (carbon monoxide) $+ O$ (free oxygen);
   (*b*) Splitting of water
   $OH_2 = 2H$ (free hydrogen) $+ O$ (free oxygen).
2. Union of the carbon monoxide and hydrogen
   $CO + 2H = CH_2O$ (formic aldehyde).

This chemical work is effected by the living substance (protoplasm) of the chloroplasts, but some special source of energy or power is necessary to assist it in bringing about the above reaction. Such a source is found in the energy of sunlight, and it is therefore well to discard the name 'carbon assimilation' for the up-building work that follows the splitting, replacing it by the term **photosynthesis** (Gr. *phōs*, *phōtos*, light). The rôle of chlorophyll is to absorb sunlight and render its energy available,

[1] This also takes place in the green parts of young stem.

with which general statement we must be content here.[1] Formic aldehyde is the simplest possible carbohydrate, and serves as a starting point for the manufacture of more complex organic compounds—starch and sugar. The first visible product of photosynthesis is **starch,** which can easily be detected in a leaf that has been exposed to light for some hours. If such a leaf is boiled in water for a few minutes, soaked in warm alcohol to remove the chlorophyll, washed, and then placed in a solution of

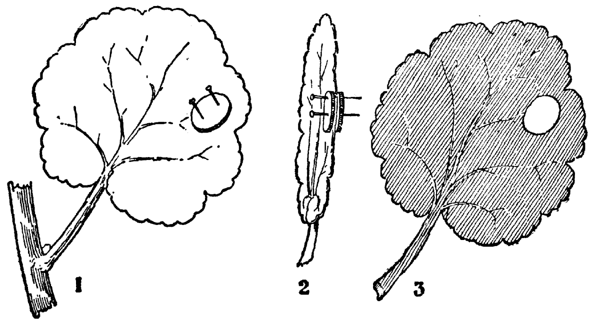


FIG. 8. PHOTOSYNTHESIS
1, Surface view, and 2, oblique view of leaf partly shaded by thin discs of cork. 3, Same leaf tested for starch (the shaded part gives no reaction).

iodine in potassium iodide (sold by the pharmacist as 'tincture of iodine'), it turns dark blue or bluish black. We know that this proves the presence of starch, for powdered starch treated with iodine gives precisely the same colour.

That **light** is necessary can be proved by testing leaves which have been kept in the dark for some time, for these do not turn blue when treated with iodine. If part of a leaf that is exposed to light be shaded by an opaque substance, that part does not react to the iodine test, but the unshaded part gives the blue colour as before (Fig. 8).

That photosynthesis depends on the presence of **chlorophyll** is also susceptible of easy proof. Some cultivated

[1] Recent research tends to show that it actively takes part in the building-up process.

plants bear variegated leaves, with whitish or yellowish patches from which chlorophyll is absent. Such leaves are found in certain varieties of holly, ivy, maple, and Portugal laurel. Application of the iodine test shows that in these cases starch is formed only in the green portions.

Lastly, **carbon dioxide** must be available or there will be no formation of starch. This can be demonstrated by placing a vigorous pot-plant on a small platform in a dish of water, together with some caustic potash (which absorbs carbon dioxide) in a suitable receptacle. The edge of the bell jar is immersed in the water, but air can get in at the top through a tube containing calcium chloride (which absorbs superfluous moisture). Before being used for this experiment the plant must have been kept in the dark for some time, so that its leaves may be starchless, for plants so kept are known to get rid of any starch that may have been formed in their leaves. If the arrangement described is placed for some hours in sunlight and the leaves are then tested with iodine, they do not turn blue, which proves that no starch is present. To fully justify the conclusion that absence of carbon dioxide accounts for this negative result, a second or control plant should be subjected to precisely the same conditions, except that a receptacle of caustic potash is not placed with it in the bell jar. Plenty of starch will be found in the leaves of this plant, which has received a supply of carbon dioxide.

Reference has been made to the **stomata** as openings which provide for the exchange of gases between the system of air spaces in the leaf and the surrounding atmosphere. That the carbon dioxide used as raw material in the process of photosynthesis enters through the stomata can be shown by smearing the under sides of some of the leaves of a pot plant with vaseline, and testing for starch after exposure to light for some time. This will be found in the untreated leaves, but not in the vaselined ones, from which carbon dioxide has been excluded by the blocking up of the stomata.

It is very important to note that the process of photo-

synthesis involves the **liberation of free oxygen,** as a by-product, for in this way the supply of that gas in the atmosphere is maintained. All animals, and the vast majority of plants, are continually breathing in free oxygen and breathing out the waste product carbon dioxide, and if there were no counterbalancing process the oxygen in the atmosphere would steadily diminish in amount and the carbon dioxide increase, until at last life would become impossible. Photosynthesis prevents this, by continually liberating oxygen from combination, and at the same time using up the carbon dioxide present in excess. The net result is that the chemical composition of air remains practically the same for very long periods of time.

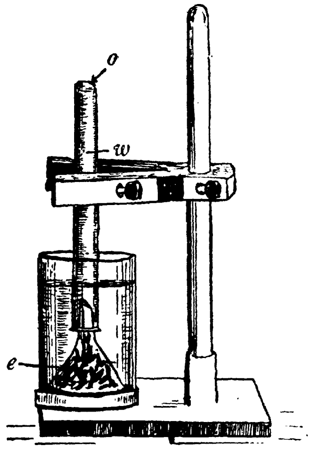


FIG. 9. PHOTOSYNTHESIS
Liberation of oxygen by green plant exposed to sunlight: *e*, water weed; *o*, oxygen; *w*, water.

That green plants do give off free oxygen when exposed to light can be proved by a very simple experiment. Vigorous young shoots, e.g. of mint or common water weed (*Elodea*), are placed in a beaker of water, covered by a glass funnel over which a test tube filled with water is inverted, and exposed to bright sunlight (Fig. 9). After a time bubbles of gas will rise into the test tube, gradually displacing the water. When the test tube is full of gas, or nearly so, it is removed, turned up, and a glowing splinter of wood plunged into it. This will burst into flame, proving the gas to be oxygen.

When a green plant is placed in the dark it is found

that the starch gradually disappears from the leaves, being in fact converted into malt sugar by the action of a complex nitrogenous substance known as **diastase.** This is an example of the important compounds termed **ferments** or **enzymes,** which play a very important part in the physiology of plants and animals. The chief point to notice is that they are able to bring about chemical changes in their surroundings without being themselves used up in the reactions involved. An enzyme is therefore able to continue its action for an indefinite time, always provided that the products of its activity are not allowed to accumulate. In this particular case the malt sugar resulting from the action of diastase on starch, being soluble and diffusible, is drained away from the leaf and conducted to other parts of the plant to serve as building material. When formed in excess of present requirements the surplus is reconverted into starch, by ferment action, in parts used for storage, such as seeds and tubers: or it may be stored as sugar (beet-root, carrot, sugar-cane).

Starch and different kinds of sugar are not the only kinds of carbohydrate built up in the plant. Other examples are **cellulose,** making up the thin cell-walls (more rarely thick ones), **woody matter,** and **cork,** the two latter constituting cell-walls that have undergone thickening. **Fats** and **oils** make up another important group of non-nitrogenous compounds, which also consist of carbon, oxygen, and hydrogen; but the oxygen is in smaller proportion. More important and far more complex than carbohydrates and fats are the nitrogenous compounds known as **proteins,** often termed 'albuminoids' in agricultural analyses, because **albumin,** of which white of egg consists, is a typical example. The percentage composition of these substances is:—carbon, 50·6 to 54·5; hydrogen, 6·5 to 7·8; oxygen, 21·5 to 23·5; nitrogen, 15·0 to 17·6; sulphur, 0·3 to 2·2. Some of them also contain phosphorus. A typical vegetable protein is **gluten,** the nitrogenous part of grain.

Breathing (Respiration).—The foliage leaf, like all other

living parts of the plant, continually breathes or respires, absorbing free oxygen and giving out carbon dioxide as a waste product. During the daytime the process is masked, as it were, by the using up of carbon dioxide and evolution of oxygen as the result of photosynthesis, and this gives rise to the erroneous idea that green plants '*breathe out* oxygen during the day.' The chief facts may be proved by an experiment with vigorous young leaves, opening buds affording good material. Sprouting potatoes will also answer the purpose. A stoppered bottle is half filled with the material selected, and placed in the dark for a couple of days, darkness being essential to eliminate photosynthesis. It will then be found that a lighted taper plunged into the bottle will go out, proving that oxygen has been used up. If some lime water is poured into the bottle and shaken up it will become milky, showing that carbon dioxide is present. The same test would of course give a positive result with ordinary air, as this contains a small amount of carbon dioxide, but the milkiness would be far less pronounced. We may therefore conclude that the air in the bottle contains more carbon dioxide than ordinary air, and the amount in excess can only have come from the leaves of the material used in the experiment.

Germinating seeds, such as peas, respire very vigorously, and are often used in the kind of experiment just described.

Transpiration.—The foliage leaf also transpires, or gives out water vapour into the atmosphere, as can easily be proved.[1] Push one of the shoots of a vigorous pot plant into a test tube, and fill up the opening of the tube with plasticine or cotton wool. Water will soon begin to collect at the botton of the tube, owing to the condensation of the water vapour transpired by the shoot. This water vapour has evaporated from the delicate cells of the spongy parenchyma into the intercellular spaces, and thence through the stomata to the exterior. That transpiration actually does take place through the stomata can

[1] The stem also transpires, though to a smaller extent.

be demonstrated without difficulty. In most leaves these minute openings are only found on the under surface, as in the india rubber plant and cherry laurel, which are convenient for the present purpose. Two such leaves are taken, and the cut ends of their stalks covered with plasticine, while the under side of one of them is smeared with vaseline, so as to block up the stomata. They are then hung up in a warm room and weighed at intervals, when it will be found that the one which has not been vaselined loses weight very much more rapidly than the other, the inference being that water vapour has continually passed out from its intercellular spaces to the exterior through the stomata.

This conclusion can be confirmed by using strips of cobalt paper, i.e. filter paper that has been soaked in 10 per cent cobalt chloride, and then dried. This is blue in colour, but turns pink when moistened. A strip of such paper is placed on the under side of a leaf, and covered with a glass slide, held in position by a spring clip. Another strip is similarly secured to the upper surface of the same leaf. After a short time the paper in contact with the under side becomes pink, while the strip fixed to the upper side remains blue. The conclusion is obvious.

Stomata constitute a self-regulating mechanism, by which transpiration can be increased or diminished in amount. The guard-cells contain chlorophyll granules and are therefore able to take part in photosynthesis. When the light is bright and the water supply abundant they become turgid by absorption of fluid, and assume a more strongly curved shape, so that the slit between them widens. In darkness or dry air they become less turgid and not so strongly curved, so that the opening narrows or even closes altogether. But we must not assume that stomata have nothing to do but regulate transpiration, for photosynthesis and respiration also involve the passage of gases through them in both directions.

Transpiration is of great importance in the nutrition of the green plant, for it has much to do with the steady

flow of crude sap through the root and stem to the leaves, and gets rid of the superfluous water. The amount escaping into the air is very considerable. For the ordinary crops of this country it has been calculated that from 250 to 300 lbs. of water are transpired for every pound of dry matter that is formed, and from 5 to 12 inches of rainfall are necessary to render this possible. It is therefore quite clear that rainfall is one of the limiting factors in crop production, and it follows that the conservation of the water in the soil becomes of great importance during a dry season. The most important means of checking evaporation from the soil itself is continual stirring of the surface layer, as by hoeing, for this breaks up the capillary spaces through which the water rises. On small areas, such as those dealt with by gardeners, the same end may be secured by **mulching,** i.e. covering the ground with straw, dead leaves, or other loose material. It is also necessary to consolidate the soil below the stirred surface by means of rolling, so that the water in the subsoil, otherwise unavailable, may rise to the roots of the crop.

There are various semi-arid regions of the globe, particularly in North America, South Africa, and Australia, where the average rainfall is only from 10 to 15 inches per annum, rendering an annual crop impossible. Such regions were formerly considered useless for agricultural purposes, but some of them are now successfully cultivated by 'dry farming,' i.e. conservation of moisture in the way just described, by which enough water is stored up in the soil to make possible a crop every other year, or in some cases two crops in three years. With the present rapidly increasing demand for foodstuffs, dry farming appears to have an important future before it.

METABOLISM

Having now passed in review some of the chief facts regarding the structure of root, stem, and leaf, and the parts which these organs play in preserving the life of the

individual, we shall do well to remember that all this complexity in structure and function can be traced back to the activity of the living substance or protoplasm that is the essential part of root, stem, and leaf. We have already seen that protoplasm exists in those units of structure known as cells (p. 4), and it is important to realize that this complex and extremely unstable substance is the seat of continual chemical changes.[1] The term **metabolism** is applied to the sum total of these changes, which are characteristic of all organisms, both plants and animals. We have also seen that very simple food is taken in by a green plant and—with the aid of sunlight in the initial stage—built up step by step until protoplasm is produced. This series of processes is fitly termed **constructive metabolism** (anabolism) by which protoplasm not only makes good the waste it continually suffers, but is also able, under favourable circumstances, to produce fresh protoplasm, i.e. to grow. On the other hand we find continual disintegrating changes constituting **destructive metabolism** (katabolism), whereby protoplasm breaks

[1] Protoplasm is not a substance of definite chemical composition capable of being expressed by a chemical formula, but a mixture of various compounds. Reinke analysed the naked protoplasm making up the body of a slime fungus (Myxomycetes), and found 75% of it consisted of water. The percentage composition of the remainder was as follows :—

1.	Proteins containing phosphorus	40·0
2.	Proteins without phosphorus	15·0
3.	Amides (simpler nitrogenous compounds) ..	1·5
4.	Fats	12·0
5.	Lecithin (phosphatized fat united with an ammonia derivate)	0·3
6.	Cholesterol ($C_{27}H_{45}OH$)	2·0
7.	Carbohydrates	12·0
8.	Resin (composed of C, H and O, in different proportions from fats and carbohydrates)	1·5
9.	Salts of organic and inorganic acids	7·0
10.	Undetermined substances	8·7
		100·0

It must not be supposed that this expresses the composition of *all* sorts of protoplasm, as it only applies to one sample taken from one kind of organism.

down, stage by stage, until simple waste products are reached, i.e. water, carbon dioxide, and nitrogenous compounds of comparatively simple character.

Energy.—This may be broadly defined as 'the power of doing work,' and the various actions—such as movement—of both plants and animals cannot be effected without manifestations of energy in its kinetic or effective form. The constructive processes of metabolism involve the conversion of actual or kinetic energy into stored or potential energy, while it is the exact opposite with the disintegrating processes.

The simplest illustration of the two kinds of energy is afforded by a mill-head, which represents a supply of **stored** or **potential energy**, not in use but ready to be used. By pulling up a sluice it comes into play for turning a wheel or turbine, and in this form is **actual**, **moving**, or **kinetic energy**. High explosives, such as cordite, are complex unstable compounds representing a store of energy. When they are caused to suddenly break down into simpler compounds this stored energy is converted into the kinetic form, which may be used for propelling a projectile or other purposes. It is noteworthy that many high explosives contain the element **nitrogen**, which unites chemically with other elements in a comparatively feeble manner, so that breaking-down takes place easily. Living matter, and proteins, are very unstable, and the element nitrogen is present in them too. This instability is characteristic of organisms as compared with mineral matter, the reason being to furnish a supply of kinetic energy as required.

That free oxygen is taken in by the breathing of plants and animals now becomes intelligible. It promotes the breaking-down processes, which are essentially processes of oxidation. It may in fact be figuratively said that all living plants and animals are constantly undergoing a process of slow combustion. Breathing further involves the casting-out or **excretion** from the body of the waste product carbon dioxide.

The nitrogenous products of waste are not directly excreted, but deposited in parts like bark, seeds, etc. which in due time are separated from the main plant.

The chief facts of metabolism are embodied in the appended diagram, commonly known as the metabolic staircase. (Fig. 10).

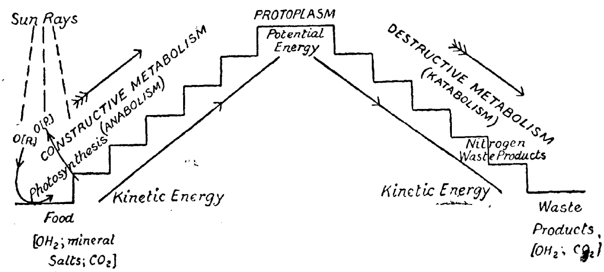


FIG. 10. METABOLIC STAIRCASE
Course of metabolic changes indicated by arrows.

SCALE LEAVES.—A word on Scale Leaves may not be out of place here. That their shape is comparatively simple is expressed by the name, and they usually serve either for protective or storage purposes. The delicate young foliage leaves within the winter buds of trees are as a rule covered and protected by scale leaves (bud scales), which are in reality modified and reduced foliage leaves. Storage is effected in the thick scale leaves covering many bulbs, such as those of lily.

CHAPTER II

THE SEED PLANT. MAINTENANCE OF THE SPECIES

HAVING now dealt with the chief facts concerning the maintenance of life in an individual seed-plant, we next turn to the function of **propagation** or **reproduction**, by which new generations of plants are produced. This may be either (*a*) *vegetative*, brought about without formation of seeds, or (*b*) *sexual*, leading to the production of these. Both are of agricultural importance.

VEGETATIVE REPRODUCTION.—In a number of grasses (including some cereals), white clover, gooseberry, and various other species, special branches known as **stolons** grow out along the ground, and these give rise to daughter plants by sending down roots from their nodes, leafy shoots growing up at the same points. There is thus a tendency to form chains of plants, which become independent by rotting of the internodes of the stolon, which at first connect them together. This 'tillering' of such stoloniferous species is largely responsible for the dense growth of vegetation on grass-land, and without it the maintenance of pasture, where grasses are not allowed to flower, would be impossible. The tillering of a cereal is of great economic importance, for it means that the sowing of a single grain may result in the production of several ears. In the case of wheat these may be as many as fifty or sixty. The formation of tillers is associated with the development of 'white roots,' which grow horizontally and are completely covered with root-hairs. They appear to be concerned with absorbing the extra amount of plant-food

necessary if tillering is to be vigorous. The formation of white roots is promoted by manuring, but different manures vary in this respect, and prolonged research is necessary before practical results can be expected. The slender **runners** of strawberry and some other plants may be regarded as elongated stolons (Fig. 11).

Vegetative reproduction of this kind is artificially induced in the gardening operation of **layering**, where a branch is pegged down to the ground until roots are produced, when the connection with the parent plant is severed. An even more direct method is that of taking **cuttings**, while **budding** and **grafting** involve planting a part of one species in another, the union brought about being so intimate that the development of roots by the bud or graft is not necessary.

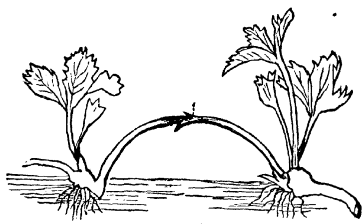


FIG. 11. RUNNER OF STRAWBERRY (*Fragaria vesca*)

Many plants propagate by means of **underground stems** (Fig. 12), and when these are narrow they are comparable to runners which have sunk below the surface. A notorious agricultural example is couch-grass (*Triticum repens*), that spreads itself with great rapidity by means of these subterranean branches, which may be yards in length. Each node of such a branch can produce a distinct daughter-plant by sending roots downwards and a shoot upwards. The power of doing this is retained even if the branch be cut into hundreds of pieces, and nothing short of complete removal from the soil will get rid of this troublesome pest.

A thickened underground stem, in which reserve food-materials are stored, is termed a **rhizome**, good examples being iris and Solomon's seal.

It sometimes happens that underground branches swell up by accumulation of reserve food, and these are known as **tubers**, familiarly illustrated by potato and Jerusalem

artichoke. The 'eyes' of a potato are in reality buds, each growing in the axil of a scale-leaf. Everyone knows that potatoes are grown by planting the tubers, either

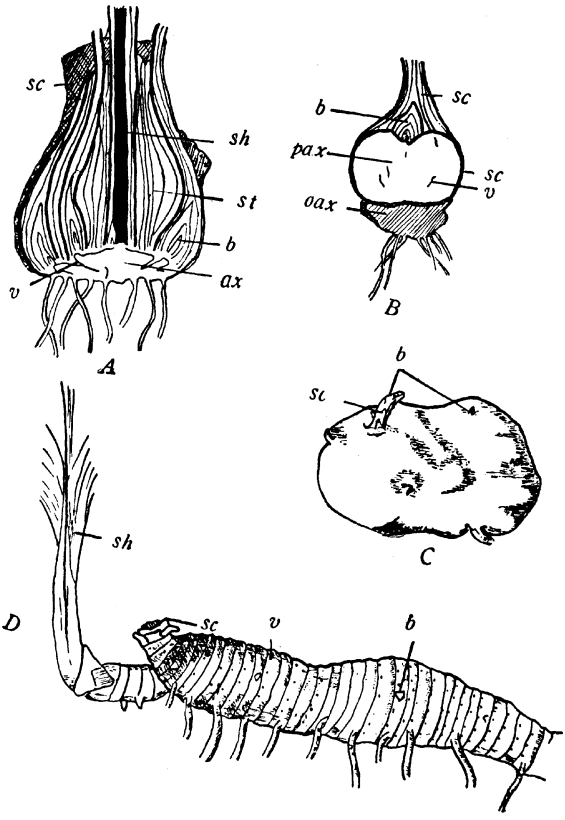


FIG. 12. UNDERGROUND SHOOTS

A. Longitudinal section through Daffodil bulb in April. B. Ditto through Crocus corm. C. Potato tuber with developing buds. D. Piece of Iris rhizome in spring; *sc*, scales formed by leaf-bases; *st*, leaf-bases thickened for storage; *sh*, this year's shoot bearing foliage leaves; *b*, bud; *ax*, abbreviated stem (disk); *oax*, old corm; *pax*, new corm.

whole, or cut into pieces (sets), of which each must be possessed of at least one eye. An eye grows into a new

plant by giving rise to an upwardly growing shoot, from the lower part of which roots are developed. The nutritive substances, mostly starch, stored in the tuber, serve as food for the young plant.

Corms and Bulbs.—In typical cases the main shoot of a plant grows vertically upwards and by elongation of its internodes assumes the form of a cylinder, or, more strictly speaking, a very gently tapering cone. There are some species, however, where this primary shoot does not elongate, but becomes a storehouse of food, and may be compared to a large thick bud. In Crocus and Cyclamen, for example, the stem itself becomes dilated, to form a **corm** (solid bulb) enveloped by the scaly bases of the leaves. The stored food in this is used up in the formation of a flower, causing the corm to shrivel. After flowering is over a new corm is formed above the old one, and this is destined to give rise to a flower in the following year. It is, in fact, a case of vegetative reproduction by an annual plant, which before shrivelling up and dying originates a successor. But the process goes further than this, for secondary or daughter corms arise as buds in the axils of the scaly leaves.

A **Bulb** (Fig. 12), such as that of tulip or onion, possesses thickened leaves crowded on a plate-like stem, technically known as the ' disk.' But a new bulb is not produced on top of the old one, vegetative reproduction being in this case limited to the formation of daughter bulbs in the axils of some of the thickened leaves. In agricultural language the term ' bulb ' is often incorrectly applied to thickened roots such as those of turnip and mangel.

SEXUAL REPRODUCTION.—This is the process resulting in the formation of **seeds**, without which a species cannot be maintained in full vigour for an indefinite period. A very striking agricultural example is that of the potato, which in farm practice is not raised from seeds, but vegetatively from tubers. This answers very well for a time, but after the lapse of some seasons the particular variety begins to degenerate, and ultimately has to be abandoned. This

is why the favourite varieties of to-day have supplanted others formerly in vogue, and are destined to give way in their turn to new kinds, grown from seeds in the first instance.

The Flower.—It is a matter of common knowledge that flowers have to do with the production of seeds, and they are in fact shoots which are specialized for this purpose. The stem-part of such a shoot is known as the **receptacle** (thalamus or torus), and as its internodes do not elongate the **flower-leaves** which it bears are crowded together, much as the foliage-leaves of a daisy or dandelion form a sort of rosette for a similar reason. There are four kinds

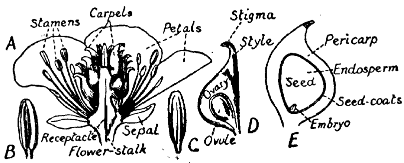


FIG. 13. BUTTERCUP FLOWER

A. Vertical section. B. Outer side of an anther, showing two lobes, each with slit for liberation of pollen. C. Inner side of ditto. D. Carpel in section. E. Fruit in section. Enlarged to different scales.

of flower-leaf, known as sepals, petals, stamens, and carpels, arranged in order from outside inwards.

The structure of a simple flower is perhaps best illustrated by examining that of any species of buttercup (Fig. 13). It will be seen that this is **regular**, i.e. possessing the same kind of symmetry as a wheel or star, and all the flower-leaves are perfectly free from one another, so that they can be picked off individually. Outside are five green **sepals** (collectively forming a **calyx**), which are obviously leaves, and these are followed by five bright yellow **petals** (together making up a **corolla**), which alternate with the sepals, and may be regarded as coloured leaves. At the base of each petal is a little pit, in which the sweet liquid called nectar is formed or secreted. This **nectary** is covered by a minute scale, the **nectar cover**. It is convenient to speak of the calyx and corolla, taken together, as the **perianth**.

The two remaining sets of flower-leaves are directly concerned in the formation of seeds, the outer set—**androecium**—consisting of numerous thread-like **stamens**, and the inner set—**gynaecium** (pistil)—being made up of a number of little green **carpels**. The former may be regarded as male, and the latter female, and a flower like this with both sexes represented is said to be **bisexual** (hermaphrodite), as is the case in the majority of common types. Each stamen consists of a stalk (**filament**), and a thickened end (**anther**), within which is developed a fine yellowish dust, the **pollen**, consisting of innumerable **pollen-grains.** Stamens are not much like leaves, but develop like these as lateral outgrowths from the nodes of a stem (here the receptacle), and in white water lily we find a gradual transition from petals to stamens. The 'doubleness' of an ordinary cultivated rose is due to the fact that many of the stamens have become petals.

Each little green carpel is divisible into three regions—a curved tip, the **stigma**, with a roughened and sticky surface, a short **style** immediately below this, and a swollen flattened **ovary**. By cutting open the carpel we shall discover that the ovary is hollow, and contains a minute pale body, the **ovule**, attached by a stalk to the lower part of the cavity. Ovules are of particular interest because they are capable of development into seeds.

A carpel is in reality a folded leaf, the edges having united so as to form the ovule-containing cavity. This is clearly seen in certain species related to the Buttercup, i.e. marsh marigold (*Caltha*), larkspur (*Delphinium*), monkshood (*Aconitum*), and columbine (*Aquilegia*). Examination of one of these will reveal the presence of several large carpels, each containing a number of ovules, and readily split open along the side to which these ovules are attached. In the abnormal blossoms of double-flowering cherry the carpels are in the form of small green leaves, some of which have partly unfolded and others completely so.

PHYSIOLOGY OF THE FLOWER.—Two successive processes are necessary before ovules can become seeds. The first of

these is **pollination**, or transfer of pollen to the stigma, and this is followed by **fertilization**, in which a minute quantity of living substance (protoplasm) derived from a pollen-grain fuses with a minute cell (**ovum** or **egg-cell**) contained in the ovule.

Pollination may be brought about in a number of ways, characteristic of different species. Since in the buttercup, as in most other flowers, stamens and carpels are associated, it might be supposed that as a general rule pollen would be transferred from the anthers of the former to the stigmas of the latter, i.e. that **self-pollination** would usually take place. This, however, is not the case, for the buttercup is adapted to attract insects, which unconsciously transfer pollen from one flower to the stigmas of others, thus bringing about **cross-pollination**. This is the object of the bright colour of the corolla, the effect being increased by the association of a number of flowers and a number of distinct plants. Many a meadow in spring presents an almost continuous yellow surface, rendering it extremely conspicuous, and easily visible to any insects in the neighbourhood. Once attracted, they are rewarded by provision of nectar, and by the abundant pollen, which is extremely nutritious, and produced to an extent unnecessary for the requirements of the plants themselves. It is probable, too, that buttercups exhale a sufficiently strong odour to attract insect visitors, and this is obviously the case in many other species, such as rose, sweet violet, and narcissus.

Although self-pollination is not excluded, it is at first less likely than cross-pollination, for the pollen of the outer stamens is shed before the stigmas have become receptive, but later on the pollen from the inner stamens can fall directly upon the stigmas, thus leading to selfing if crossing has not already taken place. There are, indeed, some kinds of plant (e.g. dog violet) which, late in the season produce small flowers that do not open and in which self-pollination necessarily takes places. There are, on the other hand, a good many common species, especially trees, which make cross-pollination a certainty, since the stamens and carpels

are in distinct flowers (male and female, or staminate and pistillate), which may be borne on the same or different plants, as in hazel and hop respectively. In such cases pollen is usually transferred by the wind, and the flowers are inconspicuous, there being no need to attract insect visitors. Colour, odour, and nectar, are consequently absent.

But in a number of species possessing distinct male and female flowers pollination is effected by insects, and, as might be expected, such flowers are conspicuous, as may be observed in cucumber and vegetable marrow. Should these be kept in closed frames so as to exclude insects, fruit and seed will not be produced, unless artificial pollination is effected by means of a small brush. This method is largely resorted to by plant-breeders who wish to control seed-production, and make it their business to raise new varieties by crossing some of those that already exist.

Fertilization.—(Fig. 14).—In order that the details may be understood it is necessary to describe briefly the structure of an **ovule**. This is attached to the ovary by a stalk (**funicle**), and covered by two delicate skins (**integuments**), except at one spot (**micropyle**), where a little gap is left. The ovule contains a mass of small-celled tissue (**nucellus**), in which is imbedded a delicate structure known as the **embryo-sac**. This possesses a central **nucleus**, and three minute **antipodal cells** at the end remote from the micropyle, while adjoining this is another group of three cells, the **egg apparatus**, consisting of two small **synergidae**, and a somewhat large **ovum** or **egg-cell** that lies more deeply.

A pollen-grain contains two nuclei, one vegetative and the other generative (male). On reaching a stigma the grain begins to germinate in the sticky fluid which is to be found there, and an excessively delicate **pollen-tube** is formed, which grows through the loose tissue of the style into the cavity of the ovary, and ultimately reaches the micropyle of an ovule. The generative nucleus is carried down in the pollen-tube, and in the tip of this divides into

two male nuclei, one of which enters the egg-cell and fuses with its (female) nucleus. It is this fusion that

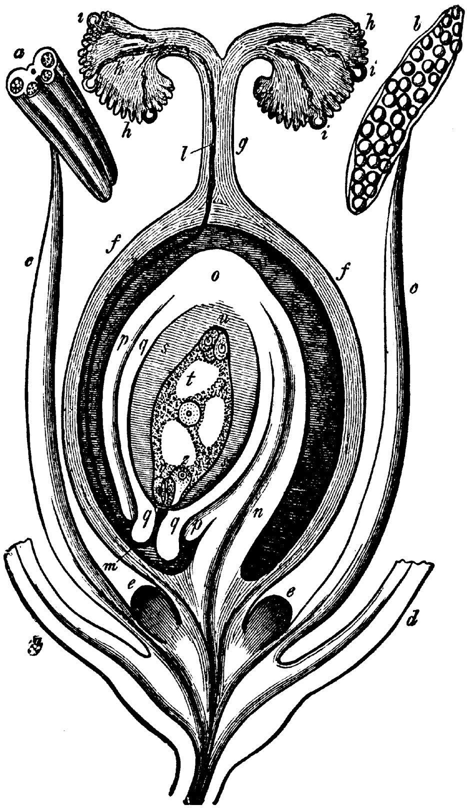


FIG. 14. POLLINATION AND FERTILIZATION

Diagram of a very simple flower in longitudinal section: *a* transverse section of an anther before liberation of pollen, showing two lobes, each with two pollen-sacs; *b*, anther splitting open longitudinally, showing liberated pollen-grains; *c*, filament; *dd*, bases of sepals and petals which have been cut away; *e*, nectary; *f*, wall of ovary; *g*, style; *h*, stigma; *iii*, germinating pollen-grains; *klm*, a pollen-tube that has traversed the style and entered the micropyle; *n*, stalk (funicle) of ovule; *o*, base of ovule; *p* and *q*, outer and inner integuments; *s*, nucellus of ovule containing embryo-sac; *t*, one of the vacuoles in the embryo-sac, below which is seen the rounded nucleus from which the endosperm originates; *u*, base of embryo-sac enclosing the three small antipodal cells; at the other end of the embryo-sac, next the micropyle, is seen the egg-apparatus, consisting of the two synergidæ and (*v*) the egg-cell or ovum (*z*).

constitutes **fertilization,** and the fertilized egg-cell now undergoes a series of divisions resulting in the formation of a small mass of cells. Part of this mass becomes the **embryo, germ**, or **plantlet**, which is the essential part of the seed, and under favourable conditions can grow into a fresh plant. The second male nucleus migrates from the tip of the pollen-tube into the embryo-sac, and fuses with the central nucleus of this. This is followed by active division, resulting in the formation of endosperm, described below in the account of the seed.

FRUIT AND SEED.—When a buttercup has finished flowering the sepals, petals, and stamens drop off, leaving the carpels, which undergo considerable enlargement as they ripen and the contained ovules become seeds. If, for the sake of convenience, we consider a single carpel, we shall find that the fertilization of the egg-cell in its ovule not only results in the development of a plantlet, but also stimulates growth in the rest of the ovule, which becomes a **seed**. Nor is this all. The ovary itself grows, developing into a **fruit**, in this case a small hard body technically known as an **achene**. That part of the fruit corresponding to the matured wall of the ovary is termed the **pericarp.**

Seed.—Careful examination of a buttercup seed will show that this consists of—(*a*) a short **stalk** derived from the funicle; (*b*) a tough two-layered **seed-coat**, developed from the coverings of the ovule; (*c*) a small mass of nutritive substance, **endosperm** (albumen), within this; and (*d*) a minute **embryo**. The embryo consists of a cylindrical part, destined to become the primary root and shoot of the seedling, and a pair of seed-leaves or cotyledons, which will expand and begin the work of carbon assimilation before the growth of the ordinary foliage leaves.

A seed containing **endosperm** (albumen), as a store on which the plantlet can draw in the first stage of its existence, is said to be **albuminous**. That of the buttercup is inconveniently small for examination, and in laboratory work is usually replaced by the large seeds of the castor-

oil plant, which have a similar structure, and are easily obtainable from any pharmaceutical chemist.

Many ripe seeds are devoid of endosperm (albumen) and therefore called **ex-albuminous**, as in leguminous plants, such as pea, bean, and clover. The large size of the broad bean makes it particularly convenient for examination, especially after it has been soaked in water overnight (Fig. 15). On one of its edges will be seen a black patch, the **hilum**, which marks where a short stalk was attached when the bean was in the pod or fruit. If the seed is wiped dry and then gently squeezed, moisture will exude from a minute hole at one end of the hilum. This corresponds to the **micropyle** of the ovule, and here the primary root of the seedling will grow out during germination.

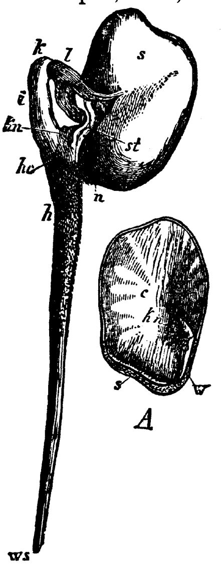


FIG. 15. SEED OF BROAD BEAN (*Vicia faba*)

A. Seed with one seed-leaf removed: *c*, the remaining seed-leaf; *w*, primary root; *kn*. primary shoot; *s*, seed-coats, *w*, primary root. B. Germinating seed: *s*, seed-coats; *l*, part of ditto torn away; *n*, scar where stalk was attached; *st*, stalk of one seed-leaf; *ik*, primary stem above seed-leaves; *hc*, very short part of ditto (hypocotyl) below seed-leaves; *h*, primary root; *ws*, tip of ditto; *kn*, bud in axil of one seed-leaf.

Two **seed-coats** can be peeled off, exposing the **plantlet** or **embryo**, which consists of—(*a*) two swollen **seed-leaves** (cotyledons) crammed with stores of food in the form of starch granules and minute aleurone grains composed of proteins; (*b*) the **radicle** or primary root; and (*c*) the **plumule** or primary shoot. The last can only be seen when the seed-leaves are separated, but the triangular radicle, pointing to the micropyle, is visible even before the seed-coats are removed.

Fruit.—Fruits are either dry or succulent, according to the texture of the pericarp. The **achene** of a buttercup is

a dry fruit with a tough membranous pericarp, which does not split open to liberate the single seed. A grain of wheat or other cereal is a somewhat similar fruit technically known as a **caryopsis.** It contains one large albuminous seed, in which the embryo lies on one side and possesses only a single seed-leaf or cotyledon. (Fig. 16). The pericarp is fused with the seed coats.

In marsh marigold, larkspur, monkshood, and columbine, each carpel becomes a dry fruit containing several seeds, and splits open along one edge to liberate them. This type of dry fruit is termed a **follicle.** The flowers of leguminous plants possess but one carpel, which also becomes a dry fruit containing a number of seeds. But this opens differently from a follicle, for it splits along both edges when the seeds are ripe. It is known as a **pod** or **legume.**

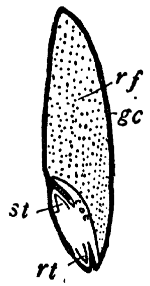


FIG. 16. CARYOPSIS

Diagrammatic longitudinal section through oat-grain (enlarged): *gc*, covering of grain, consisting of pericarp fused with seed-coats; *rf*, endosperm; *rt*, primary root; *st*, primary shoot; the scutellum is seen applied to the lower part of the endosperm.

Still another type of dry fruit is found in cruciferous plants, so called because they possess four petals arranged in the form of a Maltese cross. Such familiar plants as cabbage, rape, turnip, and mustard, belong to this group. There are two carpels, fused together into an elongated gynæcium, and the ovary is divided into two compartments each containing a number of ovules. The resulting fruit is either a much elongated **siliqua,** or a shorter **silicula.** When ripe two valves split off, leaving the seeds attached to the edges of a partition (replum) that divided the ovary into two compartments. Many fruits, however, are pulpy or **succulent,** and it is to these that the term fruit is applied in ordinary language. The **stone-fruit** or drupe of a cherry or plum will serve as an example. It is formed from a single carpel, and the kernel is the seed, while the external skin, the edible pulp below this, and the hard wall of the stone, have all been developed from the pericarp.

Dispersal of Seeds.—It is clearly desirable for seeds to be scattered or dispersed, so that they do not germinate close to the parent plant, and some of them get a chance of growing up in places not fully occupied by vegetation. There are many agents by which such dispersal is promoted. Sometimes the plant itself helps to scatter the seeds, as in violet and broom, where the fruits spring open when ripe. Many seeds and fruits are adapted for **wind dispersal**, e.g. the hairy seeds of willow and the downy fruits of thistle and dandelion. The same purpose is furthered by the wing-like expansions of the fruits of elm, maple, and sycamore. Some plants have **hooked fruits** which cling to the coats of animals and may be transported to considerable distances. Well-known examples are furnished by goosegrass (cleavers) and burdock. Edible or **succulent fruits**, such as cherry, are a device for securing dispersal by birds. The kernel or seed is protected by the hard wall of the stone from the processes of digestion.

Germination of Seeds.—The embryo or plantlet contained in a seed remains in a dormant condition until winter is over and favourable conditions for further growth or germination return with the spring. For this three things are essential:—(1) a supply of water; (2) a suitable temperature; and (3) access of air, containing the free oxygen necessary for the process of breathing, which is particularly vigorous in young plants.

Without sufficient **moisture** the young plant is unable to pierce the coverings of the young seed, and its roots could not feed in perfectly dry soil. It is clear, therefore, that ordinary agriculture cannot be carried on successfully in regions where the rainfall is very small in amount or where rain never falls. The methods of dry farming, however, by which soil moisture is conserved (p. 26), are enabling farmers to obtain crops in regions where the rainfall is so small that ordinary agricultural methods fail, and in this way arid regions are being brought under cultivation in many parts of the world.

A given kind of seed will not germinate until the **tempera-**

ture is raised to a certain **minimum**, or if it is increased above a certain **maximum**, while there is an **optimum** temperature between these limits which is most favourable for this process. The minimum, maximum, and optimum temperatures for a few species are given in the appended table.

GERMINATION TEMPERATURES
(in degrees Fahrenheit)

	Minimum.	Optimum.	Maximum.
Wheat	41	81	99
Barley	41	83	100
Mustard	32	83	99
Turnip	46	89	109
Cucumber	56	93	115

That oxygen is essential for germination can be proved by placing some seeds in a bottle of water from which air has been expelled by boiling, when they will swell up but nothing further happens. If at the same time a similar batch of the same kind of seed is kept moist and air allowed free access germination will take place readily. Mustard and cress are convenient species for such experiments, and if they are used the second batch may be sown on a damp piece of flannel.

The interesting question here arises as to how the food stored in the endosperm of an albuminous seed gets into the embryo or plantlet which adjoins or is imbedded in it. Take, for example, a grain of wheat. Here we find a plantlet with a single seed-leaf or cotyledon, of which the central part (scutellum) rests against a large mass of cellular endosperm containing two chief kinds of reserve material, **starch** and protein. The first is in the form of comparatively large grains, and the second exists as very minute **aleurone grains** packed in the cells of the surface layer. By persistently chewing a few wheat-grains a little sticky mass will ultimately remain in the mouth. This is the protein known as **gluten**, derived from the aleurone grains.

During germination two kinds of **ferment** or **enzyme** (see p. 23) are formed in the seed, which act, respectively,

on the starch and gluten, converting them into soluble substances that readily diffuse into the developing plantlet, and serve as its first food. The ferment acting on starch, **diastase**, transforms it into malt sugar (maltose). Advantage of this is taken in the process of malting to obtain the sugar required for conversion into alcohol in the subsequent operation of brewing. The grains of barley are spread on a floor, and induced to germinate by exposing them to moist heat. The sprouts will be found to have a distinctly sweet taste. At a certain stage of germination the grains are thrown into boiling water, which destroys the diastase, and then crushed into malt. The subsequent process of alcoholic fermentation, by addition of yeast, will be dealt with elsewhere.

In a somewhat similar fashion the gluten in the seed is converted into a soluble diffusible form of protein by the action of another kind of ferment, known as a **protease**. When wheat or barley germinates in the soil the food derived from the starch and aleurone grains of the seed tides over the difficult period while roots and a green shoot are being developed, and by the time this store of nutriment is exhausted the young plant is able to feed in the way that has been described.

When, as in a bean seed, reserve materials are stored in the cotyledons, they are converted by ferment action into soluble substances that diffuse into the plumule and radicle as these develop during germination.

SEED TESTING.—Thanks to a movement that originated many years ago in Denmark, most farmers are now fully alive to the necessity of using high grade seed. Germinating capacity, identity as regards species, and freedom from impurities, are the chief points of importance. Purity and germinating capacity are calculated in percentages, and what is called the **real value** is obtained by multiplying together the percentages for these two qualities, and dividing the product by 100.

CHAPTER III

FARM ANIMALS—THEIR STRUCTURE AND FUNCTIONS

PART at least of the crops, including grass, grown on a farm, together with purchased 'artificial' food, such as the various kinds of cake, are used as the raw materials for producing meat, milk and wool. It is therefore worth while to acquire an intelligent knowledge of the structure of the body in farm animals, and of the uses or functions of the various organs of which this consists. The different kinds of stock—oxen, sheep, goats and pigs—also the horse and dog, like ourselves belong to the great phylum of **Backboned** or **Vertebrate Animals**, and to the class of **Mammals**, distinguished by hot blood of constant temperature, hair-clad bodies, and the possession of milk-producing organs by the female. Any such animal possesses two-sided or **bilateral symmetry**, involving not only a distinction between right and left halves, which are mirror-images of each other, but also between front (anterior) and back (posterior) ends, and upper (dorsal) and under (ventral) surfaces.

There are considerable differences in structure between horse, ox, etc. partly in accordance with the varying nature of the food; but the functions of the body are carried out in much the same way by all of them, and some of the chief points are embodied in the following account.

REGIONS OF THE BODY

The body of a farm animal consists of head, neck, trunk, tail, fore-limbs, and hind-limbs. The front part of the

trunk is the chest or **thorax**, which contains the heart and lungs, while the remainder is known as the belly or **abdomen**, and this lodges the greater part of the digestive organs, the kidneys, the bladder, and the internal organs of reproduction.

The walls of the thorax are supported by a continuous bony framework. Above is part of the backbone, and to this are hinged numerous pairs of **ribs**, which are attached

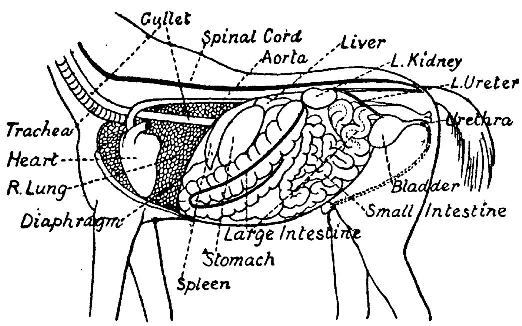


FIG. 17. STRUCTURE OF HORSE (From left side. Diagrammatic). Left lung removed

below to a **breast-bone** or **sternum**. By muscular action the ribs, carrying with them the sternum, are moved downwards and forwards so as to increase the size of the thorax as air is *inspired* or taken into the lungs; after which they move upwards and backwards, mainly by elasticity, so as to diminish the size of the thorax when air is being breathed out or *expired*. There is a curved partition, the **diaphragm** or **midriff**, between the cavity of the thorax and that of the abdomen, and this also plays a part in the movements of breathing. It has a muscular margin and its convex surface is directed forwards. As the ribs and sternum swing downwards and forwards it becomes a good deal flatter, thus increasing the size of the thorax from before backwards, and promoting the flow of air into the lungs. But it relaxes and resumes its curved shape as the ribs and sternum move backwards and upwards, thus helping in the breathing out of air.

METABOLISM

The cycle of chemical changes described by this name when dealing with the seed plant (p. 26) also takes place in an animal, but the ascending part of the metabolic staircase is much shorter than the descending part, for the food is complex, so that constructive work begins at a higher level.

THE FOOD OF ANIMALS

We have seen (p. 19) that the green plant, thanks to its power of utilizing the energy of sunlight, is able to build up very simple compounds into organic matter, thus bridging the gap between non-living and living things. Animals as we know do not possess this power, but require food which is for the most part of complex nature and solid character. Green plants serve as a supply of such food in herbivorous animals like the horse or ox, and although some mammals are carnivorous, devouring flesh, yet these depend in the long run on the organic substances manufactured by plants.

The food of such an animal as horse or ox must include **water**; **mineral substances** (salts of lime) wherewith to make the hard parts of bones and teeth, together with common salt; and complex organic compounds of three sorts—(*a*) **Carbohydrates**, such as starch and sugar, consisting of carbon, hydrogen, and oxygen, the last two being in the same proportion as in water (OH_2). (*b*) **Fats and Oils**, composed of the same three elements, but with a larger proportion of hydrogen. (*c*) **Proteins** (albuminoids) such as the gluten of grain and the nitrogenous part of fodders. These are exceedingly complex substances, chiefly made up of carbon, hydrogen, oxygen, nitrogen, sulphur, and sometimes phosphorus (see p. 23). (*d*) **Vitamines.** These are accessory food substances of which the chemical nature is unknown. Very small quantities of them are essential to life. Their chief sources are butter-fat, other animal fats and oils (but not lard), grain, and fresh vegetable substances.

This complex food is not present everywhere, like the simple liquid and gaseous food of green plants, so that animals usually possess active powers of locomotion enabling them to seek out the nutriment they require, and they are of compact form in adaptation to this end.

DIGESTIVE ORGANS AND DIGESTION

Since animals subsist very largely on solid food they possess an internal cavity into which this is taken for the purpose of **digestion**, i.e. conversion into a soluble form. It is then absorbed into the blood-vessels directly or indirectly, and is pumped by the heart throughout the body to serve as building material for repair and growth. That part of the food which is not or cannot be digested passes out of the body as **faeces** or **dung**. This serves as a valuable manure because, after undergoing certain disintegrating processes, it becomes plant food.

The digestive tube, or **alimentary canal**, into which the food is taken, and which passes from one end of the body to the other, is divided into several regions differing in size and structure, according to the work they have to perform. The mouth, bounded by flexible **lips**, opens into the mouth-cavity, containing the **tongue** and **teeth**, and passing at the back into the throat-cavity or **pharynx**, with which the cavities of the nose also communicate. The pharynx narrows into the **gullet** or **oesphagus**, a narrow muscular tube that traverses the neck and thorax, pierces the diaphragm, and then opens into a greatly expanded region, the **stomach**. This communicates with a **small intestine**, followed by a **large intestine**, which opens to the exterior by the **anus**.

The abdominal cavity is lined by a moist membrane, the **peritoneum**, which is reflected into folds by which the stomach, intestines, and various other organs are suspended and kept in place. These folds are known as the **mesentery**, which is traversed by blood-vessels, nerves, and lymphatics.

The alimentary canal is of very considerable length, particularly in herbivorous forms. In the Horse, for example, it is about eight times the length of the body.

Food, especially when of vegetable nature, takes a considerable time to digest, and if the alimentary canal were short and straight would pass through it too quickly for the thorough action of the digestive juices. Further, by increase in length of this canal the surface for absorption of digested food is increased, especially when internal folds and projections are taken into account.

During its passage through this tube the food undergoes mechanical and chemical digestion, the former breaking it down into small pieces, and the latter bringing the nutritious part of it into solution.

Mechanical Digestion.—In the case of a grazing horse the food is bitten off by the front teeth, the lips and tongue helping to bring the herbage between them, and then ground up by the flat rough crowns of the upper and lower back teeth, the cheeks and tongue keeping it between them. In the **cud-chewing** or **ruminant** forms mastication is deferred until the food is returned from the complex stomach in successive portions ('cud') to be dealt with at leisure. The action of the teeth is greatly promoted by an abundant flow of saliva ('spittle'). Swallowing is effected by the wave-like contraction of the muscular wall of the gullet, and by similar contractions the food is gradually squeezed onwards through the stomach and intestines, though it is delayed for some time in the stomach.

Chemical Digestion.—While the food is gradually being broken down into smaller and smaller pieces it is subjected to the chemical action of several digestive fluids or juices. These are manufactured or 'secreted' from the blood by special organs known as **glands**, which include the following. (1) Four pairs (three pairs in man) of **salivary glands**, that secrete **saliva** and pour it into the mouth cavity. (2) **Gastric** or **peptic glands**, microscopic tubes in the lining of the stomach, secreting **gastric juice**. (3) The **liver**, a very large reddish-brown gland situated just behind the

diaphragm, and secreting greenish **bile** (' gall ') which passes along the bile-duct into the beginning of the small intestine. Surplus bile is usually stored until required in a **gall-bladder** that communicates with the bile-duct. Among domesticated animals the horse and pigeon do not possees a gall-bladder. (4) The **pancreas** (' sweetbread '), a pale soft organ situated in the first loop of the small intestine. It secretes the **pancreatic juice** that is carried away through a pancreatic duct, and this either opens into the bile-duct or directly into the small intestine. (5) Microscopic tubes, **glands of Lieberkühn**, imbedded in the lining of the small intestine and secreting **intestinal juice.**

All these digestive juices, except bile, contain **ferments** or **enzymes** (p. 23), which convert the starch, fat, and protein of the food into soluble substances able to diffuse through moist membranes.

Saliva is a faintly alkaline liquid mostly consisting of water, but containing a small amount of a ferment, **ptyalin,** which transforms starch—that is difficult to dissolve and when dissolved will not diffuse through membranes—into soluble readily diffusible sugar (malt sugar and grape sugar). Ferments of this kind are termed **amylolytic.** Herbivorous animals, whose food is very bulky and rich in starch, secrete a large amount of saliva, as might be anticipated.

Gastric Juice is slightly acid, owing to the presence of about $\cdot 2^{\circ}/_{0}$ of hydrochloric acid, which destroys many of the injurious bacteria that are swallowed. This juice contains a ferment, **pepsin,** which converts ordinary proteins into the soluble diffusible form known as **peptone.** This and other ferments acting upon proteins are called **proteolytic.** Gastric juice also curdles milk, the earliest food of young mammals, turning the protein caseinogen which it contains into **casein,** provided salts of lime are present. Curdling is probably brought about by the pepsin, but it is sometimes ascribed to the action of a supposed second ferment, **rennin.**

Bile is a waste product made to do work before being

passed out of the body or **excreted.** It is strongly alkaline, neutralizing the acid that passes over from the stomach, promotes absorption, stimulates the movements of the intestines, and—in virtue of its alkaline constituents—**emulsifies** fats, converting them into a state of very fine division. This kind of action can be imitated by shaking up oil and a solution of sodium carbonate, which results in the production of a milk-like fluid or **emulsion.**

Pancreatic Juice is an alkaline liquid which co-operates with bile in the emulsification of fats, and also contains three characteristic ferments—(*a*) An amylolytic ferment **amylopsin**, which continues the work begun by ptyalin, (*b*) A proteolytic ferment, **trypsin**, which splits up proteins (including peptones) into simpler substances known as **amino-acids.** (*c*) A fat-splitting or **lipolytic** ferment, **steapsin**, which breaks up fats into soluble substances capable of absorption (fatty acids and glycerine).

Intestinal Juice is a watery fluid containing ferments that complete the work of pancreatic juice as regards carbohydrates and proteins. The digested food is **absorbed,** passing into the blood directly or indirectly, but the details will be better understood after the organs of circulation have been considered.

FEEDING OF STOCK. CALCULATION OF RATIONS.—In dealing with plant food we have seen that chemical analysis is misleading unless account is taken of solubility, for only soluble substances are immediately "available" for the use of the plant. A similar problem presents itself with regard to the food of animals, for a ration which appears perfect if judged by ordinary chemical analysis may in reality be very faulty, owing to the fact that only part of it can be digested. The indigestible part of course adds to the fertilizing value of the dung, but is useless to the animal. The percentage of the total carbohydrate, fat, or protein (albuminoid) in the food is termed the **digestion co-efficient** for the particular kind of food-stuff. If, for example, seventy per cent of the carbohydrates are digestible the digestion co-efficient for carbohydrates is seventy.

It is also of importance to have some standard method of calculating the proportion between the digestible nitrogenous matter (protein or albuminoid) in a given food or ration and the digestible non-nitrogenous matter (carbohydrates and fats). This is called the **albuminoid ratio.** In making such a calculation the digestible fat is multiplied by 2·3 and added to the digestible carbohydrates. The albuminoids are always expressed as units.

The feeding of animals to the best advantage is a matter which cannot be satisfactorily worked out either by the practical man or the scientist working alone. Co-operation is necessary, as is now generally recognized. Feeding experiments on a small number of animals are open to serious question, for individual animals differ from one another to a remarkable extent, and fair averages can only be obtained by dealing with large numbers. The most suitable rations depend not only upon the kind of animal, but also on the use to which it is put. Horses require different treatment from horned stock, while a horse in hard work must be treated differently from one in moderate work, and the rations of dairy cows are not the same as those of fattening oxen. It must also be borne in mind that the farmer naturally desires to make as much profit as possible, and he would do well to remember that rations suitable for a particular purpose may be made up in a number of different ways. This necessitates a careful study of prices; indeed it may be said generally that agriculture is essentially a statistical subject. For example, a new feeding stuff such as soya-bean cake is placed on the market at a comparatively low price. It is then proved to give the same result as a more highly priced cake in general use and it consequently pays to buy it. But as a result the price of the new feeding stuff rapidly advances, so that at a certain point it may *not* pay to buy it. Here, as in the case of artificial manures, the farmer should take advantage of the expert advice placed at his disposal by the Ministry of Agriculture, the Royal Agricultural Society and other authorities.

A further complication is introduced by the fact that different kinds of protein contain amino-acids of unequal value for feeding purposes, so that two sorts of feeding stuff with precisely the same albuminoid ratio may differ greatly in their nourishing power. Agricultural research will sooner or later provide us with tables expressing the relative feeding value of different proteins, but this has not yet been done.

CIRCULATORY ORGANS AND CIRCULATION

There are two fluids that move or circulate in the body, one of these being blood and the other lymph, which is colourless and transparent.

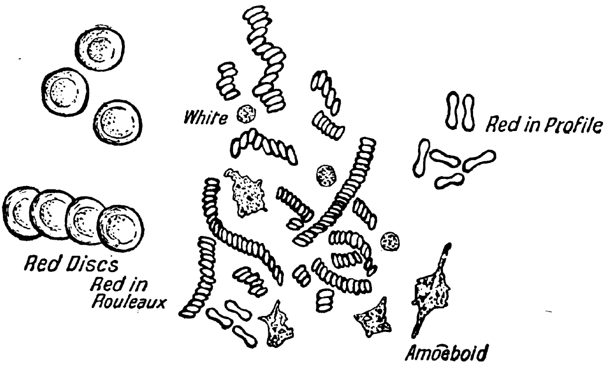


FIG. 18. DROP OF BLOOD (much enlarged)
Showing red and white corpuscles

Blood System.—Everyone knows that blood is a hot red fluid pumped by the heart through a series of tubes or blood-vessels to nearly every part of the body. Examination of a drop of blood under the microscope will show it to consist of a fluid part, the plasma, and innumerable microscopic particles, the corpuscles, which float in this, and are of two kinds—white and red (Fig. 18). **Plasma** contains the nutritive part of the food, converted into soluble substances by the processes of digestion, and forming

the building materials for repairing waste and enabling growth. It also contains some of the products of waste which have to be excreted. The **red corpuscles** are circular biconcave discs, composed of protoplasm but devoid of a nucleus, and only about $\frac{1}{3200}$ of an inch in breadth. But in an average human being they number something like thirty billions, and if these were placed side by side with their edges touching they would extend more than six times round the earth. They owe their colour to a red substance, **haemoglobin**, which possesses the remarkable power of taking up a certain amount of oxygen into loose chemical combination, and as readily parting with this to those parts of the body that require it. We can therefore describe the red corpuscles as oxygen carriers. They also carry much of the waste carbon dioxide in similar fashion.

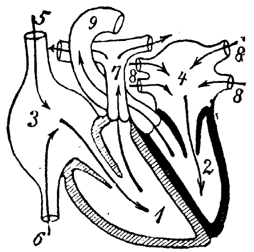


FIG. 19. HEART OF MAMMAL

Diagrammatic: 1, right ventricle; 2, left ventricle; 3, right auricle; 4, left auricle; 5, anterior vena cava; 6, posterior vena cava; 7, pulmonary artery; 8, pulmonary veins; 9, aorta. Direction of blood-flow indicated by arrows.

The **white** or **colourless corpuscles** of the blood are somewhat larger than the red ones, and much less numerous, being in the proportion of one to 500 or 600 in a healthy human being. They are of many kinds. Each such corpuscle is a fragment of semifluid protoplasm containing a nucleus, being in fact a simple kind of cell. There is no definite firm investment, and certain sorts of these corpuscles undergo continual alterations of shape, enabling them to creep about from place to place, blunt processes (pseudopods) being protruded and the rest of the protoplasm flowing after them. Corpuscles of this kind engulf and digest injurious germs, such as disease bacteria.

The **heart** is a hollow muscle shaped like a blunt cone, **with** its base directed forwards (in a quadruped). It consists of four chambers, two thin-walled **auricles** in

front, and behind these two thick-walled **ventricles** (Fig. 19). There is no direct communication between the two sides of the heart, but each auricle (right or left) opens into the corresponding ventricle. These auriculo-ventricular openings are provided with valvular flaps (three on the right and two on the left) that permit blood to flow from auricle to ventricle but not in the contrary direction. Thin-walled **veins** carry blood into the auricles, and thick-walled **arteries** carry it away from the ventricles. A vein, like a river, is formed by the union of smaller tributaries, in which the blood flows from smaller to larger and ultimately into the heart. The reverse is true for an artery, which branches into smaller and smaller vessels, in which the blood always flows away from the heart. The smallest arteries are connected with the

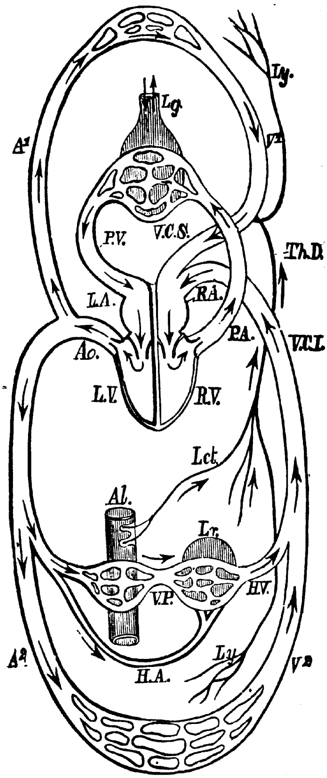


FIG. 20. COURSE OF THE CIRCULATION
(Seen from above. Diagrammatic)

Diagrammatic: *R.A.* and *L.A.* right and left auricles; *R.V.* and *L.V.*, right and left ventricles; *Lg.*, lungs; *Al.*, alimentary canal; *Lr.*, liver; *V.C.S.*, anterior vena cava, formed by union of veins (V^1) from head, neck, and fore-limbs; *V.C.I.*, posterior vena cava, formed by union of veins (V^2) from rest of body; *Ao.*, aorta, branching into anterior (A^1) and posterior (A^2) arteries; portal system includes hepatic portal vein (*V.P.*), hepatic artery (*H.A.*) and hepatic veins (*H.V.*); *Ly.*, lymphatics; *Lct.*, lacteals; *Th.D.*, thoracic duct. Flow of blood and lymph, and of air to and from lungs, indicated by arrows. Capillary networks are shown between arteries and veins, and the valves of the heart are drawn as curved lines.

smallest veins by a complicated network of microscopic tubes, the **capillaries**, of which the walls are exceedingly thin.

Course of the Circulation (Fig. 20).—It is necessary to bear in mind a distinction that is made between pure and impure blood. **Pure blood** contains relatively little carbon dioxide, is rich in oxygen, and bright scarlet in colour. **Impure blood,** on the other hand, is loaded with carbon dioxide, poor in oxygen, and dark blue in colour. The right side of the heart contains impure blood, and the left side pure blood. The pumping action of the heart takes place in two stages:—(1) the thin-walled auricles contract together and squeeze their blood into the corresponding ventricles; (2) the thick-walled ventricles then contract simultaneously, and the blood being prevented from returning to the auricles by closure of the auriculo-ventricular valves is forced into the arteries.

The left auricle receives pure blood from the lungs by the **pulmonary veins**, this flows into the left ventricle, and thence passes into the **aorta**, which is the chief artery of the body. Three pouch-like **semilunar valves** at the beginning of the aorta prevent the blood from returning to the ventricle.

The aorta curves round to the left (arch of the aorta), giving off **carotid arteries** to the head and **subclavian arteries** to the fore-limbs, reaches the middle line, and runs back just beneath the backbone as the **dorsal aorta**, which gives off a great many branches, including several to the internal organs, and ultimately forks into common **iliac arteries**, each of these dividing into an **internal iliac artery** supplying the pelvic region, and an **external iliac artery** that runs into one of the hind-limbs.

If the arteries were rigid tubes the blood would be propelled through them in a series of jerks, corresponding to successive contractions of the left ventricle. They are, however, very elastic, and therefore enlarge when blood is pumped into them. In the intervals between contractions of the ventricles their elasticity comes into play,

causing them to diminish in size, thus squeezing the blood onwards and converting the jerks from the central pump into a comparatively steady flow. The alternate enlargement and diminution in size of an artery gives rise to the **pulse**, which indicates the rate at which the heart beats.

In a horse the pulse is taken under the jaw or in the armpit, and in health there are about 35 beats per minute, though for a young foal from 100 to 120 is normal. In cattle the pulse is most conveniently felt on the under side of the root of the tail, and varies from 45 to 50 beats per minute in healthy adults ; in calves from 92 to 132.

The various arteries arising from the aorta branch repeatedly, getting smaller and smaller, and ultimately becoming continuous with capillary networks in all parts of the body, except the epidermis and its products (hair, horns, and hoofs), and cartilage (gristle). The walls of capillaries are so exceedingly thin that diffusion can take place through them. It is thus that nutritive substances and oxygen reach the tissues from the blood, and various waste products enter the blood from the tissues.

The blood which has become impure in the capillaries is drained from them by minute veins, which unite into larger and larger trunks until two main veins are formed—an **anterior vena cava**,[1] receiving blood from head, neck, and fore-limbs ; and a **posterior vena cava**, receiving blood from trunk and hind-limbs. Both of these open into the right auricle. The anterior vena cava is formed by the union of right and left **jugular veins** from the head with right and left **subclavian veins** from the fore-limbs. Veins possess numerous simple valves, flap-like foldings of their lining that prevent back flow.

The right auricle squeezes the impure blood it receives into the right ventricle to be pumped through the **pulmonary artery** to the lungs for purification. Semilunar valves,

[1] In some mammals, e.g. rodents, insectivores, and bats there are right and left anterior venae cavae. The above description applies to horse, pig, and man, where the left a. v. c. has disappeared and the right a. v. c. drains venous blood from both fore-limbs and both sides of head and neck into the right auricle.

similar to those of the aorta, prevent the blood from returning into the ventricle. The branches of the pulmonary artery are continuous with a network of capillaries in the lungs, where the blood is purified, after which it is carried by **pulmonary veins** to the left auricle.

Portal system.—The veins of the stomach and intestines, containing the products of digestion, except fats, unite together into a **portal vein**, and this, instead of opening into a still larger vein, breaks up in the substance of the liver. Here its branches become continuous with a set of capillaries which also receive pure blood from the hepatic artery, a branch of one of the vessels leaving the aorta. This capillary network is drained by **hepatic veins** into the posterior vena cava. A good deal of the sugar absorbed into the blood from the small intestine, and carried away in the portal vein, is taken up by the liver and converted into **glycogen** (liver starch) to be stored up temporarily. This is reconverted, as required, into sugar, which diffuses into the capillaries to be taken away by the hepatic veins.

LYMPH SYSTEM.—This consists of a communicating set of spaces and small tubes containing lymph, a clear fluid consisting of plasma and colourless corpuscles. The swelling typical of dropsical complaints is caused by an abnormal increase in its amount, and it is also obviously present in blisters. Lymph fills the abdominal cavity, surrounds the brain and spinal cord, is present between the two layers of the **pericardium**, a sort of double bag surrounding the heart, and also between the two layers of each **pleura**, a similar investment of either lung. Heart and lungs are in continual movement, and the layers of lymph surrounding them greatly reduce friction. The various tissues of the body are saturated with lymph, which occupies a system of irregular microscopic spaces (lacunæ) and passages. A bit of fine-grained sponge saturated with water will serve as a rough model, greatly enlarged, of a piece of tissue, the water in the sponge representing lymph. If we could insert into the bit of

sponge a network of delicate tubes full of red fluid this would correspond to capillaries containing blood. From this illustration it will be realized that lymph acts as a sort of middleman between the tissues and the blood. In the liver and spleen, however, blood comes into direct contact with the living cells making up the tissues, and even penetrates into them.

The lymph contained in the large and small spaces just described is drained away by delicate tubes, the **lymphatic vessels**, resembling small veins in structure and, like these, possessing numerous valves that only permit the lymph to flow in one direction. The majority of the lymphatic vessels ultimately open into a narrow tube, the **thoracic duct** that lies on the under side of the backbone, and opens in front into the junction of the left jugular and subclavian veins. At this point lymph is constantly flowing into the blood.

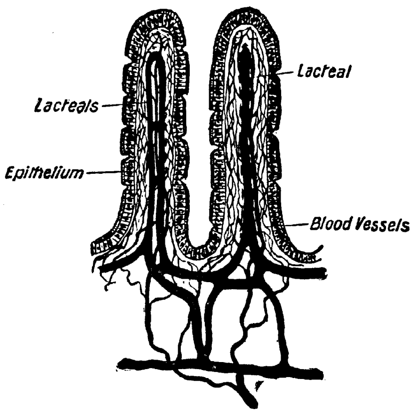


FIG. 21. TWO VILLI (enlarged and diagrammatic)

Small rounded swellings, **lymphatic glands**, may be seen here and there in the course of the lymphatics. They consist of tissue by which new colourless corpuscles are continually being manufactured.

ABSORPTION OF DIGESTED FOOD.—This chiefly takes place in the small intestine, the lining or **mucous membrane** of which is raised into innumerable minute finger-shaped projections, the villi, that collectively possess an exceedingly large absorptive surface. Each **villus** is

covered by a delicate membrane, **epithelium**, composed of a single layer of cells elongated at right angles to the surface. Under this membrane is a network of blood capillaries surrounding a minute branching tube, continuous with the lymphatics of the intestine (Fig. 21). These have received the special name of **lacteals** (L. *lac*, *lactis*, milk), because after a meal containing fat they are found to contain a milk-like fluid. The branching prolongation into the villus itself is termed a **lacteal radicle**, because its appearance suggests a rootlet.

The soluble substances resulting from the digestion of carbohydrates and proteins diffuse into the blood contained within the capillary network, while those produced by the splitting of fat are recombined within the villus into fat globules that enter the lacteal radicle, and are ultimately carried into the blood stream *via* the thoracic duct.

DUCTLESS GLANDS.—The secretions of such glands as the salivary, pancreas, and liver, are known as 'external,' because they are carried away by special tubes or ducts. But the body also contains small glands of other kind which do not possess ducts, for they produce '**internal**' **secretions** that diffuse into the blood. Such secretions contain substances called **hormones** or chemical messengers, which regulate certain bodily activities. The most important of these bodies are the thyroid and suprarenal glands, and the pituitary body.

Thyroid Gland.—This consists of two soft bodies, one on each side of the trachea near its front end, and connected together by a transverse band. They are known as 'throat bread' by butchers. The internal secretion helps to regulate the nutrition of the body, and grave disorders result from undue enlargement of the gland (as in goitre or 'Derbyshire neck'), or from its insufficient development.

Suprarenal Glands (or Adrenals).—These are two soft bodies connected with the front ends of the kidneys or placed near them. Their action is only partially understood, but they manufacture an internal secretion containing a hormone, **adrenalin**, which causes constriction of

the small arteries, and also increases the amount of sugar supplied by the liver to the blood (p. 58).

Pituitary Body.—This is a small rounded body of complicated structure attached to the under side of the brain. The action of the hormone or hormones secreted by it is complex and requires further investigation, but among other things it appears to be concerned with normal growth, and also stimulates the contraction of the muscular layers in the walls of various internal organs.

Other hormones are produced elsewhere in the body, e.g. by the pancreas and reproductive glands, and the epithelial lining of stomach and small intestine. Extracts of thyroid, suprarenals, pituitary body, etc., are now largely used in medical practice, and with extension of our knowledge these are likely to be of increasing importance.

Another organ, the **milt** or **spleen**, is also included among the ductless glands, though not known to produce an internal secretion. It is an elongated dark-red structure richly supplied with blood-vessels, and attached to the stomach by a fold of mesentery. Our knowledge of its functions is incomplete, but it appears to be concerned with the breaking up of worn-out red corpuscles and with the formation of one of the nitrogenous waste products, uric acid, excreted in the urine.

RESPIRATORY ORGANS AND RESPIRATION

Animals, like plants, **breathe** or **respire**, taking in free oxygen and giving out the waste product carbon dioxide. On the floor of the pharynx is a slit, the **glottis**, through which air passes in and out in the course of breathing. It is guarded in front by an elastic flap, the **epiglottis.** The glottis opens into a voice-box or **larynx** (the 'Adam's apple' of a human being), supported by cartilages, and continued into the **wind-pipe** or **trachea**, that runs back through the neck below the gullet. Its firm walls are strengthened by hoops of cartilage that prevent it from

collapsing. When the trachea reaches the thorax it forks into two bronchi, which enter the **lungs**, a pair of large spongy organs within which the blood is purified. Each **bronchus** branches repeatedly in a tree-like manner within its lung, each of the delicate final twigs ending in two or three rounded and somewhat elongated **air-sacs** (Fig. 22), lined by very delicate epithelium composed of a single layer of flat cells. The wall of an air-sac bulges out into a number of rounded projections (alveoli) and these are closely surrounded by a network of blood capillaries.

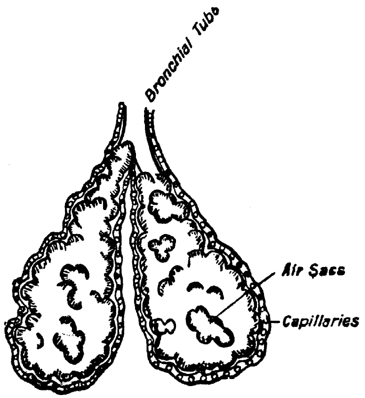


FIG. 22. TWO AIR-SACS (enlarged and diagrammatic)

The bulgings on the air-sacs, labelled "air sacs," are better termed alveoli

The movements by which air enters and leaves the lungs have already been described (p. 46), but this only concerns the larger air passages, for renewal of air in the delicate air-sacs takes place by diffusion. It is here that exchange of gases takes place, oxygen diffusing from the air into the blood, and carbon dioxide passing out of the blood into the air.

NITROGENOUS EXCRETION

The waste products of an animal partly consist—as in a plant—of nitrogenous compounds. These (urea, uric acid, and hippuric acid) are of comparatively simple chemical nature, and are **excreted** or removed from the body chiefly by way of the **kidneys**, which separate them together with water and salts from the blood. The waste

liquid or **urine** thus formed passes from the kidneys through two narrow tubes, the **ureters**, into the **urinary bladder**, and is thence ejected from the body. This is the most valuable part of farm-yard manure, the rest of which consists of dung—undigested food—together with straw or some other kind of litter.

EXCRETION BY THE SKIN

The skin consists of a protective hair-producing[1] outer layer, the **epidermis**, below which is the **dermis**, a fibrous layer richly provided with blood-vessels, lymphatic spaces, and nerves. Water, in the form of **sweat** or **perspiration**, evaporates from the skin as a waste product, and as this evaporation serves to dissipate heat a means is provided of regulating the temperature of the body. Small quantities of carbon dioxide, nitrogenous waste, and mineral salts (especially sodium chloride) are also excreted by the skin.

MUSCULAR SYSTEM

The more obvious movements of the body, such as those involved in locomotion or the chewing of food, are brought about by the **muscular tissue**, popularly called flesh or meat. This is divided into a large number of separate pieces or **muscles**, some of which are in the form of layers, as in the abdominal wall; while a great many, those of the limbs, for example, are elongated and attached to bones or other hard parts. A muscle essentially consists of innumerable microscopic **muscular fibres**, which possess the power of **contractility**, i.e. of shortening and broadening without change of bulk or volume. It is true we often speak of the *contraction* of a muscle, or say that a muscle *contracts*, but this does not mean diminution in size.

It will be convenient to take the human **biceps muscle** as an illustration. This is a spindle-shaped mass of flesh on the front of the upper arm, where it can readily be

[1] Nails, claws, hoofs, and the horns of cattle, sheep, and goats are also epidermic products.

felt (Fig. 23). When the forearm is bent or *flexed* on the upper arm this muscle will be observed to contract, i.e. to shorten and broaden. On dissection, we find that the muscle-fibres are bound together by fibrous material, **connective tissue,** which serves as a framework within which branch blood-vessels, lymphatics, and nerves. There is also a firm investment of similar nature continued at each end into strong, tough cords—**tendons**. Above there are two of these, fixed to the shoulder-blade or scapula, while below there is a single tendon attached to one of the bones (radius) of the forearm. The scapula is relatively fixed, but the radius and other bone (ulna) of the forearm are movably attached or *articulated* to the bone of the upper arm (humerus), the hinge-like elbow-joint being at the junction. It consequently follows that when the biceps contracts the forearm is pulled up. The relatively fixed end of a muscle is termed the **origin**, and the other end—attached to a movable part—the **insertion.**

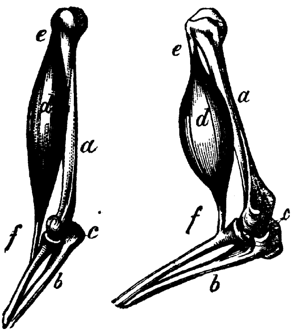


FIG. 23. BICEPS MUSCLE

Relaxed on left, contracted on right; *a*, humerus; *bc*, ulna; *d*, body of biceps; *e*, upper tendons of ditto; *f*, lower tendon of ditto, attached to radius.

The biceps, like all the ordinary muscles of the body, is under the control of the will, and its fibres are said to be **voluntary.** They are caused to contract by nerve-impulses passing from the central nervous system along a **motor nerve,** the fibres of which come into very close relation with the muscular fibres. If such a nerve be cut, no effort of the will can bring about contraction of the muscles it supplies.

Besides voluntary muscle the body also contains a large amount of **involuntary muscle,** which is not under the direct control of the will, and is composed of fibres

of somewhat different structure. Muscle of this kind makes up the heart, and is present in the walls of arteries and veins, and such internal organs as stomach, intestines, ureters, and urinary bladder. All these are hollow structures, and the size of their cavities varies according to the extent to which the muscle-fibres in their wall have contracted. All such fibres—and this applies to voluntary fibres as well—are in a partially contracted or 'tonic' condition when at rest.

Action of Involuntary Muscle.—When the muscular wall of a ventricle of the **heart** contracts, the contained cavity diminishes in size and blood is forced out. Relaxation follows, the cavity enlarges, and blood flows in from the corresponding auricle. The muscular layer of an **artery** consists of fibres running transversely, i.e. the layer is 'circular.' These fibres are usually partly contracted, but under nervous influence they may either contract less, causing the artery to enlarge, or more, diminishing its size. In this way the amount of blood flowing through an artery is regulated. The **small intestine** will serve as a final example. The muscular part of its wall consists of an external longitudinal and an internal circular layer. The size of its cavity will obviously be diminished by contraction of the latter, and as this takes place in a wave-like manner the digesting food will be gradually squeezed onwards. The longitudinal layer comes into play as the circular layer relaxes, and its contraction enlarges the cavity. The combined action of the two layers brings about the **peristaltic movements** by which the intestinal contents are carried into the large intestine, which takes over the work of propulsion.

NERVOUS SYSTEM

This system correlates the work of all the other parts of the body, and adjusts them to surroundings. It consists of an immense number of cells, neurons, supported by connective tissue. A **neuron** (Fig. 24) consists of a

nucleated part (cyton), often termed a **nerve-cell**, and slender thread-like prolongations, which are of two kinds, branching **dendrons**, and an **axon**, which is often of great length. The cyton or nerve-cell receives nerve impulses passing through the dendrons, and from it other such impulses pass out along the axon, which becomes, in very many cases, the conducting central strand (axis cylinder) of a **nerve-fibre**.

Comparison may be made with an electric system, the nerve-cells corresponding to batteries, and their slender prolongations to conducting wires. But we must not forget that we have to deal here with living batteries and living threads of communication.

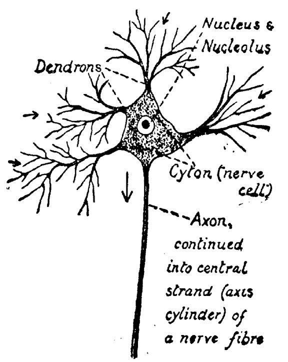


FIG. 24. A NEURON (much enlarged)

The nervous system consists of: (1) Central Nervous System; (2) Autonomic Nervous System; and (3) Nerves connected with these.

CENTRAL NERVOUS SYSTEM (Fig. 17).—This is a tube of soft substance placed near the upper surface of the body. In front is the brain, occupying a large cavity in the skull, and continued behind into the spinal cord or marrow running through a canal in the backbone. Both brain and cord essentially consist of **grey matter**, made up of nerve-cells, and **white matter**, chiefly composed of nerve-fibres. They are richly supplied by blood and lymph.

The **spinal cord** is cylindrical in form, with a core of grey matter surrounding an exceedingly small central canal and imbedded in a mass of white matter. It serves as a means of communication between the brain and all parts of the body, except the head. But in virtue of its grey matter the cord is much more than a mere

conductor of nerve impulses, and takes part in a large number of **reflex actions**, with which the brain is not directly concerned.

This is exemplified by cases of 'broken back,' where part of the spinal cord is so injured that communication with the brain is cut off. The result is that all parts below the injury cease to be under the control of the will, and there is complete loss of sensation in them. If, however, the sole of one foot be tickled the corresponding leg will be drawn up. The chain of events in this reflex action, which may be taken as a type of many others, includes :—(1) The application of an external irritation or **stimulus,** here of mechanical kind and consisting of the series of contacts constituting the tickling, (2) The inward passage of nerve impulses through nerve fibres from the skin to a group of nerve cells, a **nerve centre**, in the cord. (3) The outward passage of another set of nerve impulses from this centre, through nerve fibres to certain muscles. (4) The pulling-up of the leg by contraction of these muscles.

The **brain** consists of an axis, directly continuous with the spinal cord, and some large outgrowths from it. This axis, like the cord, is made up of internal grey matter and external white matter, and within it is a series of cavities communicating behind with the central canal of the cord. There are a number of nerve centres in the grey matter of the posterior part of the axis (medulla oblongata) which are concerned with very important reflex actions, such as those which bring about breathing movements, regulate the beating of the heart, and adjust the size of the small arteries.

The **cerebellum** is a large solid outgrowth from the hinder part of the brain axis, and overlapping its upper side. Its grey matter is partly internal, partly in the form of an external layer, the **cerebellar cortex,** divided by deep grooves into a number of narrow folds. The cerebellum is concerned with the correlation of muscular movements and the maintenance of equilibrium.

Two very large outgrowths from the anterior part of the brain axis, the **cerebral hemispheres**, cover its upper surface in front of the cerebellum. Some of their grey matter is internal, but most of it, the **cerebral cortex**, is external. The amount of this, particularly in the higher animals, is increased by the presence of **convolutions**, which may be described as winding folds separated by well-marked grooves. Each hemisphere contains a complicated cavity, communicating with that within the front part of the brain axis. A curved band, the **corpus callosum**, made up of transverse nerve-fibres, connects and co-ordinates the two hemispheres.

Part of the cerebral cortex consists of **motor centres**, in supreme control of groups of muscles, and **sensory centres**, concerned with vision, hearing, and so forth. It is also believed that the cortex is the seat of memory, intelligence, and all the higher functions of the mind.

AUTONOMIC NERVOUS SYSTEM.—This is an arrangement for controlling and regulating the action of the internal organs, but is, of course, subordinate to the central nervous system. It consists of two very narrow cords running along the under side of the backbone and continued at their front end into the cavity of the skull, where they are linked up with the brain. The name **sympathetic nervous system** is applied to the middle parts of these cords from the front end of the thorax to the middle of the loins, but older writers give this name to the whole of the autonomic system.

Each cord swells up at intervals into little rounded masses called **ganglia**, which contain nerve cells and may therefore be regarded as bits of grey matter. They are connected with the nerves of the spinal cord, and also with outlying ganglia in the abdomen and scattered nerve-cells in the walls of many internal organs.

NERVES.—These are collections of nerve-fibres which connect up all parts of the body with the central organs and serve as a means of communication. Some of them are **afferent** (L. *ad*, to; *fero*, I carry), carrying nerve

impulses *to* the central organs, while others are **efferent** (L. *efferens*, carrying out), conducting such impulses *from* the central organs.

Spinal Nerves.—These make up a regular paired series of branching white threads attached to the spinal cord, and made up of innumerable microscopic nerve fibres bound together by connective tissue, but remaining quite distinct from one another, like the wires in an electric cable. Each nerve has a double origin from the spinal cord, there being a **dorsal root**, on which there is a small swelling or **spinal ganglion**, and a **ventral root.** The white colour of these nerves is due to the fact that most of their nerve fibres are **medullated**, each of them being covered by a thin layer of fat (medulla). This is also the reason for the distinctive colour of the white matter in the central nervous system.

The fibres of the dorsal root are afferent, and many of them are **sensory**, conducting nerve impulses from sense organs. Those of the ventral root are efferent, and a large number of them are **motor**, supplying muscles and carrying nerve impulses that cause them to contract.

Cranial Nerves.—Of these there are twelve pairs, arising from the brain, and they include the nerves of the head and certain other parts. Some of them are afferent, others efferent, and others again **mixed** (like the spinal nerves), i.e. containing both kinds of nerve fibre. The more important facts are summarized in the following table. It should be noted that the numbers are given in order from before backwards.

I.	**Olfactory**	Afferent	Nerves of smell. Made up of sensory fibres running from the lining of the nose to the olfactory lobes, forward outgrowths from the cerebral hemispheres.
II.	**Optic**	Afferent	Nerves of sight, composed of sensory fibres.
III.	**Oculomotor**	Efferent	Motor nerve for most of the eyeball muscles.
IV.	**Pathetic**	Efferent	Ditto for one eyeball muscle.

V.	**Trigeminal**	Mixed	General sensory nerve for head, cavities of nose and mouth, and teeth. Motor fibres to muscles of mastication, etc.
VI.	**Abducent**	Efferent	Motor nerve for one eyeball muscle.
VII.	**Facial**	Mixed	Motor nerve for muscles of face.
VIII.	**Auditory**	Afferent	Two branches (*a*) nerve of hearing, (*b*) nerve related to balance of body.
IX.	**Glossopharyngeal**	Mixed	Nerve of taste. Motor branches to muscles of the pharynx.
X.	**Vagus**	Mixed	Afferent fibres from and efferent fibres to the pharynx, gullet, stomach, heart, lungs, etc.
XI.	**Spinal Accessory**	Efferent	Motor nerve for some of the neck muscles.
XII.	**Hypoglossal**	Efferent	Motor nerve for tongue muscles.

Autonomic Nerves.—These connect the ganglia already described (p. 68) with the internal organs. Their fibres are **non-medullated**, i.e. devoid of a coating of fat, and consequently not white but pale in colour.

SENSE ORGANS

These may be described as a sort of intelligence department, by which the brain is made aware of what is happening in the body and outside it. What are known as the organs of special sense bring the body into touch with its surroundings. As the result of the action of certain agents, or **stimuli**, such as light and sound, we become aware of things, in other words we experience **sensations**. Waves of sound, for example, stimulate our auditory organs, the final result being sensations of hearing.

In the production of a sensation some stimulus acts on so-called **end-organs**, from which nervous impulses pass along a chain of neurons, ultimately reaching a sensory centre in the cerebral cortex (p. 68). End-organs are usually, but not always, specialized cells or groups of cells, mostly elongated in shape. It is only possible here to describe very briefly the chief sense organs.

The Skin.—This is the most extensive of all the sense organs, and it may be taken also to include the linings of the cavities of the nose and mouth. It has to do with sensations of three kinds: (*a*) sensations of **contact** (touch), for which the stimulus is mechanical; (*b*) sensations of **heat** and **cold**, where the stimulus consists of heat-rays acting from a greater or less distance; (*c*) sensations of **pain**, due to various stimuli and serving a warning purpose.

Organ of Taste.—This consists of part of the lining of the mouth, more particularly that covering the tongue. Groups of **taste-cells** are to be found here and there, mostly localized in small projections or papillæ. The stimulus consists of substances in solution, and true sensations of taste are of four kinds only, distinguished as sweet, bitter, salt, and sour.

Organ of Smell.—The upper part of the lining of the two cavities of the nose contains numerous **olfactory cells,** which can only be stimulated by substances in a gaseous condition. A sensation of smell is either pleasant or unpleasant, fragrant or the contrary. The sense of smell helps in the finding of food, as in animals that hunt by scent, and also tests the character of food. By it enemies or noxious substances can be detected and avoided, and animals of the same species sought out.

The cavities of the nose open behind into the pharynx, so that food in the mouth can be smelt, and what we call 'taste,' in the broadest sense, is really a combination of taste, smell, and touch. In feeding stock the best results cannot be obtained unless animals devour their food with zest, so that the smell and taste of this must be taken into consideration. Sugar feeds, for example, have considerable value because they impart an appetizing character to the rations.

Organ of Hearing.—The stimulus in this case consists of sound waves, which are to-and-fro movements or vibrations of the air. These are collected by an external flap, the **pinna,** to which the name 'ear' is limited in

ordinary language. They then pass down a short passage and impinge upon a **tympanic membrane**, which is thereby thrown into vibration. These vibrations are carried across an internal cavity, the 'drum' of the ear, by means of a chain of little bones, ultimately reaching a small bag of very complicated shape, the **membranous labyrinth**, sheltered in the side-wall of the skull. The labyrinth is full of fluid, and suspended in a fluid-filled cavity. Part of it consists of a spirally coiled tube (cochlea), the lining of which contains numerous **auditory cells**. Nerve-fibres pass from these to the brain along one branch of the auditory nerve.

The greater part of the labyrinth, however, is concerned with the balance of the body, and this part is provided with numerous sense cells, which are affected by every movement, and from which nervous impulses continually stream to the brain along a branch of the auditory nerve. Without the information thus supplied the brain would be unable to bring about the muscular adjustments that are continually necessary for the maintenance of equilibrium.

Organ of Sight.—The eye may be regarded as a spherical camera, sheltered in a depression of the skull, the **orbit**, provided with protective eyelids, and continually kept clean by the tears, which are secreted by a special gland. After washing the front of the eye they pass into the cavity of the nose through a narrow tube. Several small muscles are attached to the eyeball, and these are able to move it in any required direction.

The wall of the eyeball is composed of three coats:—(1) A firm fibrous **sclerotic** (the 'white' of the eye), the front part of which is transparent and strongly curved. This is the **cornea**, comparable to a window for admission of light. (2) The **choroid**, which lines most of the sclerotic, is dark in colour, and provided with numerous blood-vessels. In the front of the eye it does not form a lining to the cornea, but flattens out into the **iris**, a muscular diaphragm with a central aperture, the **pupil**, which can be

either contracted or dilated, so as to regulate the amount of light passing through it. This diaphragm is the coloured part of the eye visible from the exterior through the cornea. (3) The **retina**, which lines the choroid behind the iris, and may be compared to the sensitive photographic plate placed at the back of a camera. It contains end-organs, the **rods** and **cones**, on the side next the choroid, and therefore pointing away from the light.

The eyeball contains transparent refracting structures by which pictures of external objects are focussed on the retina. The most important of these is the **lens**, an elastic biconvex body situated behind the iris. The space between the cornea and iris is filled with a watery fluid, the **aqueous humour**, and a jelly-like substance, the **vitreous humour,** occupies the cavity of the eyeball behind the lens. In a state of rest the eye is focussed for distant objects, but it can be adjusted or accommodated for near vision.

The retina is transparent except for a thin layer of pigment-cells next to the choroid. Rays of light pass through it to the rods and cones, which are thus stimulated, and originate nerve impulses passing along the optic nerve to the brain.

REPRODUCTION

The process of sexual reproduction has already been described in the case of seed plants (p. 33), and in animals it is essentially the same. A minute **ovum** or **female cell** is fertilized by fusion with it of an exceedingly small **male cell** or **sperm**, commonly known as a spermatozoon (Fig. 25). The latter consists of a **head**, containing the nucleus, and this is covered by a thin layer of cytoplasm continued into a body, and this again into a thread-like **tail and end piece.** The sperm is able to swim, head first, by lashing movements of its tail, and some kind of chemical attraction exerted by the ovum directs its course. Motile sperms are also possessed by many seedless plants,

such as ferns and mosses, and even a small number of the lower seed plants.

In the **uterus** (womb) the fertilized ovum grows into an **embryo** or **foetus,** from the abdomen of which an **umbilical cord** runs to a structure known as the **placenta**, which varies a great deal in shape and structure in the different orders of mammals. In the mare or sow, for example, it surrounds the foetus as a membrane richly provided with blood-vessels, and thickly studded with small projections fitting closely into pits in the mucous membrane lining the uterus. The use of the placenta is to bring the blood

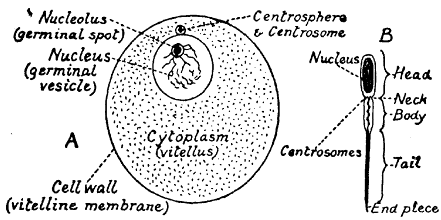


FIG. 25. SEX-CELLS. A, Female (ovum), much enlarged
B, Male (sperm), very much enlarged. The centrosomes[1] are represented as two black dots.

system of the foetus into close relation with that of the mother, and it is in this way that the developing animal is nourished, receives a supply of oxygen, and gets rid of its waste products.

Poultry, of course, are **oviparous**, laying eggs that develop if they are exposed to a sufficiently high temperature; the necessary warmth being supplied by the body of the sitting hen, or by the artificial arrangement called an incubator. Details are given in the volume on *Poultry Keeping* in this series.

[1] A centrosome is a specialized particle in the cytoplasm of an animal cell, that is concerned with division of the nucleus.

CHAPTER IV

CLASSIFICATION OF PLANTS—SEED PLANTS

THERE are an enormous number of different kinds or **species** of plants, the ones of special interest to the farmer including not only those he cultivates, but also a great many weeds, fungoid pests, and microscopic forms. Some of these last are responsible for many diseases that attack crops and stock, others prepare plant food in the soil, and still others have much to do with the processes of dairying.

EVOLUTION

It is now generally held that the existing species of plants have arisen from pre-existing forms by a process of **evolution** or change, but opinions differ as to the precise way in which this has come about. Accepting the truth of the evolution theory we can attach a meaning to the common statements that such-and-such plants are closely 'related,' or but distantly related. There is, for example, a close resemblance between all grasses, including the cultivated cereals, and this is best explained as the result of near kinship; while, on the other hand, the marked differences between a fern and a mushroom become intelligible on the assumption that the two plants are but very remote relatives. The volume on *Feeding and Breeding of Stock*, in this series, gives information regarding modern views on evolution.

CLASSIFICATION

Were we in possession of all the facts it would be possible to construct a genealogical tree representing the vegetable kingdom, the leaves corresponding to species, the twigs to groups of species, and the branches to still larger assemblages of plants. And when we attempt to classify plants (or animals), i.e. to group or arrange them according to their resemblances and differences, and to embody this classification in a diagram, we shall find that a branching tree-like form best expresses the facts, as might be expected, since we are in reality endeavouring to construct a pedigree.

Species.—Although we can say in a general sort of way that a species, e.g. red clover, is a 'kind' of plant, it is practically impossible to frame an exact definition, for the boundaries between related species are not always so sharp as formerly supposed. The best test is a physiological one, for we find that species—say of seed plants—that are distantly related, cannot be crossed, and though crossing may be effected between two that are allied, the offspring resulting, termed **hybrids**, are infertile. But there are exceptions to the rule, so that even this physiological test may break down on application.

Varieties.—A single species may appear in two or more different forms, each known as a **variety**, as in the case of the bramble or blackberry, of which at least five well-defined varieties are recognized. Some cultivated plants present a number of varieties, known as 'artificial,' because they have arisen under conditions brought about by man for his own ends. Most of the different kinds of wheat and other cereals are of this nature, and modern plant-breeding has for its aim the production of desirable varieties of crop plants. The rust-resisting varieties of wheat produced by Biffen afford a good example. The potato may be given as another illustration. It has already been pointed out (p. 32) that this crop is propagated vegetatively by means of the tubers, but a profitable yield cannot be obtained if this is carried on for too many

seasons, as degeneration gradually sets in. It follows that new varieties have constantly to be introduced, and these are raised from seed, their production being an important industry.

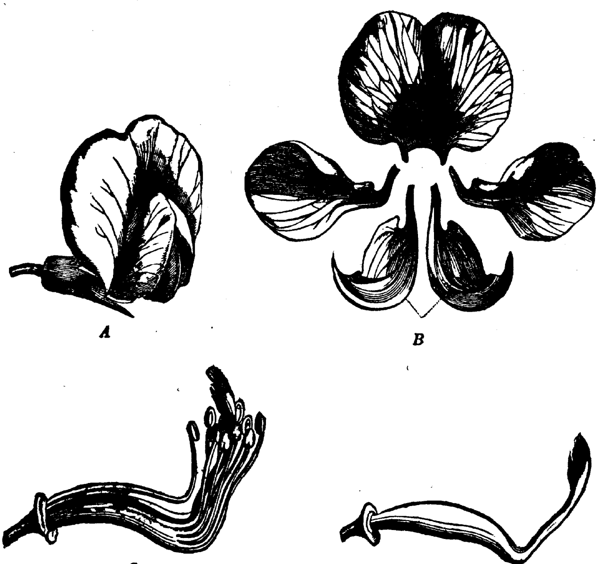
Varieties may be regarded as species in the making and, as a rule, related varieties are readily crossed with production of fertile offspring, technically called **mongrels** to distinguish them from the infertile hybrids produced by crossing allied species.

Genera.—Two or more closely related species are grouped into a **genus**, comparable to one of the smallest twigs of the genealogical tree, the leaves borne by this twig representing the included species. Experts of all nationalities possess a common language in so far as the scientific names of plants are concerned, by which much confusion is obviated. Each plant is given a double name, the first being that of its genus and the second that of its species. Comparison may be made with the name of a human being, but the two parts are placed in reverse order. In the case of John Jones the first or Christian name is less important than the second or surname; but white clover, for example, is technically known as *Trifolium repens*, where *repens* is the species and *Trifolium* the genus. The latter is more important than the former and therefore comes first. A similar principle is employed in lists of voters, where John Jones becomes Jones, John, for his more easy identification.

The clover genus includes four other species common in cultivation:—*T. pratense*, red clover; *T. hybridum*, alsike; *T. incarnatum*, crimson clover (the 'Trifolium' of farmers); *T. minus*, yellow suckling clover. If the plant is a variety, a third name may be added, as, for example, in the case of cow-grass, a variety of red clover, and of which the scientific name is *Trifolium pratense perenne*.

Orders.—Genera are grouped into larger assemblages known as **orders**, and we may take that including the clovers as an example. These belong to the genus

Trifolium, with which are allied a number of other genera including well-known cultivated species, e.g. sainfoin (*Onobrychis sativa*), lucerne (*Medicago sativa*), field pea (*Pisum sativum*), and field bean (*Vicia faba*). The genera Trifolium, Onobrychis, Medicago, Pisum, and Vicia, with a great number of others, collectively make up the important order of **Leguminosae**, or leguminous plants, distinguished by the following characters (Fig. 26) :—



A B C D

FIG. 26. FLOWER OF EDIBLE PEA (*Pisum sativum*)
A, oblique view ; *B*, petals ; *C*, stamens and pistil ; *D*, pistil.

foliage leaves compound (i.e. split up into leaflets), flowers butterfly-shaped (in all native British species), fruit a pod (p. 41), seeds exalbuminous.

From what has been said it will be seen that the 'pulse crops' belong to Leguminosae : other familiar crop plants and cultivated species are included in other orders, a few

of which may be mentioned. The Cabbage Order, **Cruciferae**, includes plants which are mostly herbs, with characteristic flowers (Fig. 27) possessing a corolla of four petals arranged in the form of a Maltese cross, six stamens (four long and two short), and two carpels fused together. The fruit is a siliqua (p. 41) and the seeds are exalbuminous. *Examples:* cabbage, turnip, rape, and mustard. Carrot and parsnip belong to the order **Umbelliferae** (Fig. 28), which includes herbs with numerous small flowers crowded together into umbels, where a number of diverging flower-stalks grow out from the same point, but are of different lengths, so that the flowers they bear together make up a coloured surface on which insects can settle. In most cases a number of umbels are associated together into a 'compound' umbel. The parts of the flower are in fives, except the carpels, of which there are two, united together. The fruit, when ripe, splits into two parts, each containing an albuminous seed. What a farmer would call the 'seed' of carrot or parsnip really consists of these fruits. The order **Solanaceae** (Fig. 29) includes the potato and various other species, in which the conspicuous flowers have their parts in fives, though the carpels, as in the preceding order, are but two in number and fused together. Here, however, the fruit is succulent, forming what is commonly known as the potato 'apple,' which contains a large number of albuminous seeds. The tomato is a related species, and

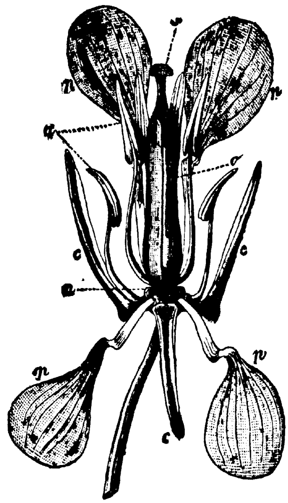


FIG. 27. CRUCIFEROUS FLOWER OF RAPE (*Brassica rapa*) slightly enlarged and partly dissected; *c*, *c*, *c*, three of the four sepals; *p*, *p*, *p*, *p*, petals; *a*, two of the six stamens; *o*, ovary; *s*, stigma; *n*, a nectary.

everyone must have noticed the many seeds contained in the large juicy fruit. Sugar beet and mangel wurzel belong to still another order, the **Chenopodiaceae** (Fig. 30), where

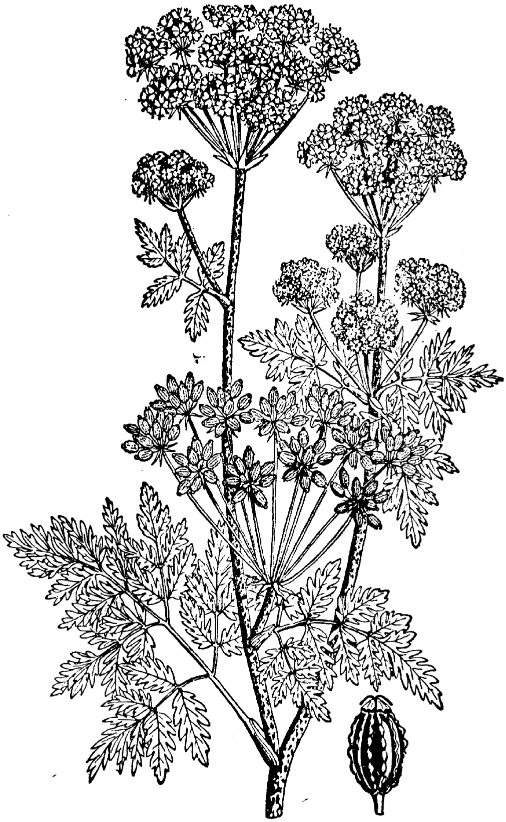


FIG. 28. AN UMBELLIFER
Hemlock (*Conium maculatum*): a fruit enlarged, below to right.

the flowers are small and inconspicuous, but built on much the same plan as those of the potato. Wild beet (*Beta maritima*) is a widely distributed shore-plant, which has

become adapted to air and soil containing a good deal of salt. Garden beet, sugar beet, and mangel wurzel are all varieties of this species that have arisen in the course of cultivation. The mangel crop is often increased by application of a top-dressing of common salt, which is intelligible when we remember that its ancestor, the wild beet, lives

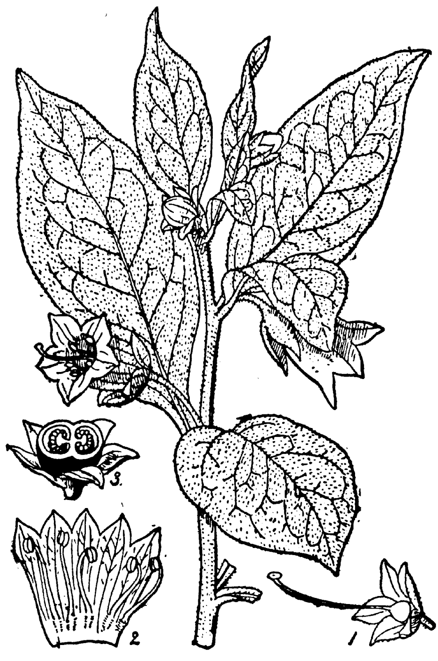


FIG. 29. SOLANACEOUS PLANT—DEADLY NIGHTSHADE (*Atropa belladonna*)
1, flower with corolla and stamens removed, showing calyx and pistil; 2, corolla cut open, with the five attached stamens; 3, fruit, cut across, showing two chambers and two groups of seeds.

by the sea. Mangel 'seeds' are really fruits, each containing two or three seeds, but each fruit of the wild species contains but a single seed.

Classes.—All the preceding orders, with many others, have certain points in common, which are obvious enough

when pointed out. There is a main or tap-root, and a cross section through the young stem shows that the vascular bundles are arranged in a ring and contain cambium (p. 15). Those of the leaf ('veins') form a complicated network. The sepals and petals, and very often the stamens, are arranged in twos, fours,

FIG. 30. A CHENOPOD—COMMON OR WHITE GOOSEFOOT (*Chenopodium album*): 1, a flower, enlarged, showing five-leaved perianth, five stamens, and pistil with two stigmas.

or fives, and there are two seed-leaves or cotyledons. All orders presenting these characters are grouped together into a special class, that of **Dicotyledons,** the name having reference to the number of cotyledons present in the seed.

In certain other orders of flowering plants, such as the

Liliaceae (including lily, tulip, hyacinth, onion, and leek), and **Gramineae** (grasses), there are marked differences from dicotyledonous forms. The root has no main axis, but consist of a mass of fibres, and on cutting a cross-section through the stem we shall find that the vascular bundles are scattered, and not arranged in a ring. There is no cambium. The veins of the foliage leaves do not form a complicated network, and the chief ones run more or less longitudinally. When, as in Liliaceae, the flower is conspicuous, its parts are arranged in threes; and the embryo of the albuminous seed possesses only one seed-leaf or cotyledon. These features, or most of them, are characteristic of the class of **Monocotyledons.**

FIG. 31. COCK'S-FOOT GRASS (*Dactylis glomerata*)
Below, left, a spikelet enlarged; right, a flower, still further enlarged.

Grasses (Fig. 31) are of such great agricultural importance that it is necessary to give a few details about them. The stem is known as a **haulm**, distinguished by swollen nodes and hollow internodes. The foliage leaf has a narrow blade (but no stalk) which passes down into a sheath that clasps the stem, but does not form a complete tube as its edges are not united together. A small outgrowth, the **ligule**, will be found at the junction of blade and sheath. Its characters are of importance for the recognition of the different species. Grass **flowers** are small and inconspicuous, and crowded together in little groups or **spikelets**, varying in arrangement according to the species. Scale-leaves found in the region of the flower are known as **bracts.** Those of grasses and cereals are firm and membranous in

texture, and in the operation of threshing are removed as the 'chaff.'

A spikelet of wheat will serve as an example of the flowers of grasses (Fig. 32). Outside this are two large bracts called **glumes**, enclosing two or three perfect flowers, and some minute barren ones. Each flower is enclosed in and protected by two other bracts, an **outer pale**, with a short awn, and an awnless **inner pale**. There are no obvious sepals or petals, but two minute delicate scales, the **lodicules**, are usually considered as the remains of a perianth. The three stamens have slender stalks, to which the long anthers are loosely attached. The gynæcium consists

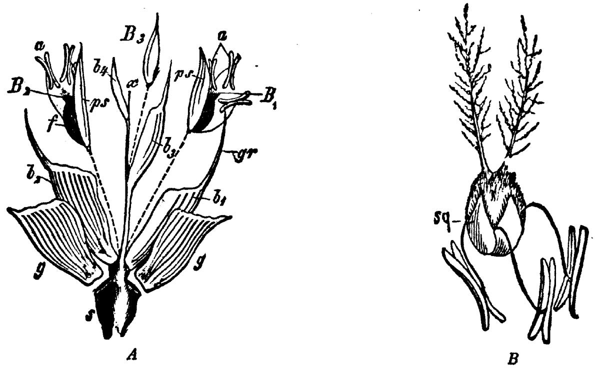


FIG. 32. WHEAT (*Triticum sativum*)

A, dissected spikelet (enlarged): *x*, axis, with thickened base *s*; *g*, outer glumes; b_1 to b_4, outer pales, the last sterile; *gr*, awn; *B*, to B_3, flowers displaced from axils of outer pales; *ps*, inner pales; *a*, anthers; *f*, ovary. *B*. Flower (further enlarged): *sq*, lodicules.

of a single carpel[1] made up of a large ovary (containing a single ovule), two short styles, and two feathery stigmas.

The inconspicuous nature of the wheat flower is due to the fact that it is not adapted to pollination by insects, but to the transfer of pollen by wind. When the mature flowers open, the stamens hang out, and the abundant dry pollen that they produce is scattered by every breath of

[1] Some authorities consider that the two styles and stigmas indicate the presence of two carpels.

air, some of the grains being caught by the feathery stigmas of other flowers. As a rule, however, wheat and other cereals—except rye—are for the most part self-pollinated and self-fertilized.

The wall of the ripened ovary (pericarp), adheres closely to the single seed, so that a ripe grain of wheat is in reality a fruit (p. 41). In a grain of barley the two pales remain attached.

Phyla or **Sub-kingdoms.**—Plant classes are assembled into four great groups, each known as a **phylum** or **sub-kingdom**. Of these the highest is that of **Seed Plants** or **Spermaphyta,** which are also known as Flowering Plants or Phanerogamia. There are two divisions or **sub-phyla** of seed plants—(1) **Angiosperms**, in which the seeds are enclosed in an ovary, as in all Dicotyledons and Monocotyledons; and (2) **Gymnosperms**, in which the seeds are borne on the surface of unfolded carpels as in the cone-bearing trees, such as pine, larch, and cedar.

We can now fully classify our original example, red clover:—

species	*pratense*	class	*Dicotyledons*
genus	*Trifolium*	sub-phylum	*Angiosperms*
order	*Leguminosae*	phylum	*Spermaphyta*

WEEDS

The name "weed" is applied to worthless plants, such as thistles and docks, wherever they occur; and also to useful forms growing in the wrong place, as wheat in grass land, or grasses in a turnip field. Harold Long, in *Common Weeds of the Farm and Garden*, gives a detailed list of 301 species of flowering plants that are more or less undesirable, the worst of these on arable being couch-grass (*Triticum repens*), charlock (*Sinapis arvensis*), docks, thistles, and coltsfoot (*Tussilago farfara*); while the commonest weeds in grass land are thistles, buttercups, Yorkshire fog-grass (*Holcus lanatus*), creeping soft-grass

(*H. mollis*), docks, daisies, and plantains, (species of *Plantago*).

Uses of Weeds.—Where ground is left without a crop, weeds undoubtedly prevent nitrates from being washed out of the soil, and if ploughed in they increase the amount of humus. They can also be used for making compost, and serve as an incentive to hoeing and other acts of tillage which bring the soil into good condition.

Injurious Influence of Weeds.—Not only do weeds trespass on the space available for cultivated plants, but they compete with these for food, light, air, and warmth. Many of them shelter insect and fungoid pests, some actually destroy crop plants, and others are poisonous to stock. Many careful comparisons have been made between the yield on land kept free from weeds and that where they have been allowed to flourish, and from these it is clear that neglected ground, in extreme cases, may mean a cash loss of 50%. This, however, does not take into account the cost of cleaning operations.

Preventive Measures.—The employment of clean seed is essential; weeds should be prevented from seeding, e.g. thistles should be regularly cut; implements of tillage should be kept clean; and rubbish likely to contain weed-seeds should not be deposited on arable land. It is also obvious that hedges, ditches, and headlands, should be kept as free from weeds as possible.

Remedial Measures.—(1) *On arable.* Much can be effected by thorough cultivation, such as ploughing followed by harrowing; hoeing and hand-pulling; and spudding (as in the case of thistles). Two root-crops in succession give abundant opportunities for cleaning land; and weeds can also be 'smothered' out by growing clover, lucerne, sainfoin, or mustard.

Sprays can sometimes be employed to advantage, especially for charlock, which can be eradicated by using a 4 or 5 per cent solution of copper sulphate at the rate of 40 gals. per acre; or the same amount of 7 per cent solution of iron sulphate. The latter can also be used in the form

of powder—3 or 4 cwts. per acre. Some **artificial manures** not only supply plant food but also kill weeds. Kainit, for example, destroys charlock, wild radish, black bindweed, speedwell, chickweed, nettles, groundsel, corn-flower, and mayweed.

(2) *On grass land.*—Pastures can be improved by occasional haying, while weedy meadows benefit by grazing. Mixed grazing is in all cases of advantage. Tall weeds, can be got rid of by methodical cutting. If, for example, thistles are scythed down for two successive years, once in June and twice in July, but few of them survive.

Spraying rarely does much good on grass land, but manurial applications are useful in some cases. Salt kills nettles and the oxeye daisy, while liming keeps down sorrels.

LOWER PLANTS

The remaining three phyla are **Pteridophyta** (Ferns and Fernlike Plants); **Bryophyta** (Mosses and Liverworts); **Thallophyta,** a vast assemblage including all the lowest plants. It is convenient to speak of these three phyla collectively as the **Seedless** or **Flowerless Plants** (Cryptogamia). Pteridophyta and Bryophyta are of little importance to agriculture, though the former include the Bracken Fern, sometimes used for bedding down stock; while peat litter is mostly composed of the Peat Mosses, which belong to the Bryophyta. The Thallophyta, however, embrace many species that play a very important part with regard to crops and stock, and the two next chapters will be devoted to them.

CHAPTER V

CLASSIFICATION OF PLANTS. THALLOPHYTA—TRUE FUNGI

THE lower plants making up the phylum Thallophyta differ greatly among one another in size. shape, and mode of life. But in all of them the plant-body is a **thallus** distinguished by negative characters, there being no distinction, or at most no clear distinction, between root, stem, and leaf; and no well-defined tissues as in higher plants. A great many are microscopic, and in large numbers of these the body is **unicellular**, i.e. consists of a single cell: other forms, such as brown seaweeds and toadstools, are relatively large and conspicuous.

ALGAE AND FUNGI.—Thallophytes are conveniently though not very scientifically divided into these two series, distinguished by the presence or absence of chlorophyll. Since **Algae** possess this green colouring matter they are able, like crop plants, to feed on simple substances, and are dependent upon light (cp. pp. 19-22). Here are included a great variety of green, red, and brown seaweeds, of which the last two contain chlorophyll, though this is cloaked by the presence of other pigments. Algae are also to be found in fresh water, an example being afforded by the green scum often seen on the surface of ponds and ditches: others, again, live on land, as in the case of the microscopic species that make up the greenish coating on tree-trunks and palings. It is unnecessary to give any account of Algae here, for they are of little agricultural importance, though seaweeds find a use as manure.

Fungi may be of various colours, as may be seen by inspecting moulds, mildews, and toadstools, but they never contain chlorophyll, and when of green colour (e.g. common green mould) owe it to the presence of quite a different pigment. It follows, therefore, that they cannot, like algae and crop plants, utilize very simple substances as food, and they are either **parasites** preying upon the living bodies of other organisms (e.g. the crop-pests known as 'potato disease' and 'wheat rust'), or **saprophytes** finding nourishment in the products of decay (e.g. mushroom and green mould). Another consequence of the absence of chlorophyll in fungi is that they are not dependent upon light, which may even be harmful to them. Many microscopic living species in the soil play a very important part in the preparation of nitrogeneous plant food.

CLASSIFICATION OF FUNGI.—Fungi are divided into numerous groups, only a few of which require mention here. They are not closely related to one another, for they appear to have been derived from various groups of algae, of which they may be regarded as the degenerate descendants. It is convenient, however, to divide them into: (1) TRUE FUNGI, including all the obvious species, and (2) FALSE FUNGI, embracing the microscopic yeasts and bacteria.

TRUE FUNGI

Examination of the body of a true fungus will show it to be made up of delicate branching tubes, **hyphae**, as may be very well seen in common **white mould** (*Mucor mucedo*), a saprophyte that will probably make its appearance on horse-dung or damp bread placed in any convenient receptacle and covered over to prevent drying up. (Fig. 33). A plant-body made up of such branching threads is technically known as a **mycelium**, and its appearance recalls the root-system of a higher plant. It is in fact adapted to a similar purpose, i.e. searching for food.

White mould also illustrates the typical methods of

reproduction among true fungi, which may either be asexual or sexual. Slender aerial hyphae grow vertically upwards, and each of them swells at its tip into a rounded case, **sporangium**, looking like the head of a pin. Within this a large number of microscopic **asexual spores** are produced, each of which is capable of growing into a fresh plant. The less frequent process of **sexual reproduction** consists in the outgrowth of short branches from adjacent

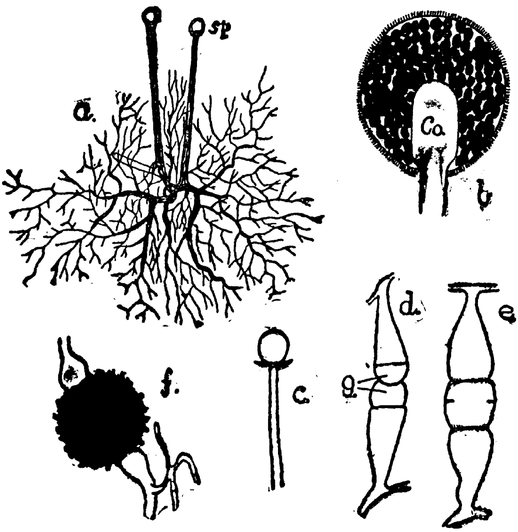


FIG. 33.—WHITE MOULD (*Mucor*)

a, Mycelium, slightly magnified, showing two of the long-stalked sporangia (*sp.*); *b*, sporangium, much enlarged, with numerous spores and central column (*Co.*); *c*, burst sporangium, in which only the column and a small part of the wall remain; *d* and *e*, conjugation of gametes (*g.*); *f*, mature zygospore.

hyphae of the general mycelium. By formation of a cross-wall the tip of each branch is cut off as a **sexual cell** or **gamete**. The two gametes come into contact, and fuse together into a **zygote**, and the process is comparable to the fertilization of an egg-cell by a smaller male cell or sperm. But here the two fusing cells are of equal size and similar appearance so that it is not possible to distinguish between

male and female, and in such cases the zygote is called a **zygospore**. This becomes surrounded by a strong rough coat, and we can speak of it as a 'resting' spore, because germination may be postponed for some time. Mucor, like many other fungi, can also produce thick-coated asexual resting spores. In this case part of an ordinary hypha swells up, a cross-wall is formed on either side of it, and a firm investment is developed. However formed, resting-spores serve the important purpose of preventing the extinction of the species by tiding over unfavourable periods, remaining dormant until the conditions are suitable for germination. True Fungi may be divided into Lower and Higher, both including important crop-pests.

LOWER TRUE FUNGI

White mould, described above, is a typical lower fungus, and the leading character shared by it and its allies is the continuous nature of the hyphae, which are not divided into a series of cells by cross-walls or septa, except in connection with the reproductive processes.

Black scab or **wart disease** (*Chrysophlyctis endobiotica*).

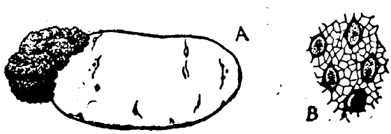


FIG. 34. BLACK SCAB (*Chrysophlyctis endobiotica*)
A, infected potato (reduced). B, section of diseased tuber, showing five spore-forming cells (much enlarged)

This notifiable disease attacks potatoes, and is much favoured by continuous cropping. (Fig. 34). Diseased tubers present roughened black outgrowths, which have arisen by the fusion of wart-like projections that make their appearance in the neighbourhood of the eyes. The fungus responsible is a degenerate type, and thin sections examined

under the microscope reveal the presence of rounded cells within which spores are formed. Some of these are motile **zoospores**, which swim through the moisture of the soil and spread the disease, while others are thick-walled **resting-spores**, that remain dormant in the ground ready to infect the next crop that is planted. They have been known to remain alive for as long as four years, in the dormant state. It is clear, therefore, that continuous cropping should be avoided, and that the soil should be thoroughly disinfected by means of gas-lime or similar agents, while infected plants must be burnt. It should also be remembered that some of the varieties cultivated are more liable to infection than others.

FIG. 35. OAT SMUT (*Ustilago avenae*)
A, panicle attacked from below upwards (x ½); B, spikelet in early stage of infection (x 2); C, spores (x 500); D, germinating spore, producing chains of yeast-like buds (x 500).

Some of the ears in a ripening field of oats will often be of a blackish colour, owing to attack by the **Oat Smut** (*Ustilago avenae*), which destroys the flowers and prevents the formation of grain (Fig. 35). The dark colour is due to the presence of innumerable microscopic **spores**, which are liable to cling to the surfaces of ripe oat-grains. Should such a grain be sown the spores germinate at the same time as the grain, sending out hyphae that penetrate the delicate seedling. As the young oat-plant grows the mycelium

of the fungus ramifies within it, but does not interfere with development or lead to sickliness. When, however, the oat-flowers make their appearance, they are attacked and destroyed by the parasite, which then produces its countless spores. By pickling the seed-corn in a solution of copper sulphate (1 lb. to 4 gals. water for every 4 bushels of grain) or diluted formaline (1 pint 40 per cent formaline to 36 gals. water for 40 to 50 bushels of grain) the disease may be prevented. This process covers the grains with a poisonous film that kills the spores as soon as they begin to germinate.

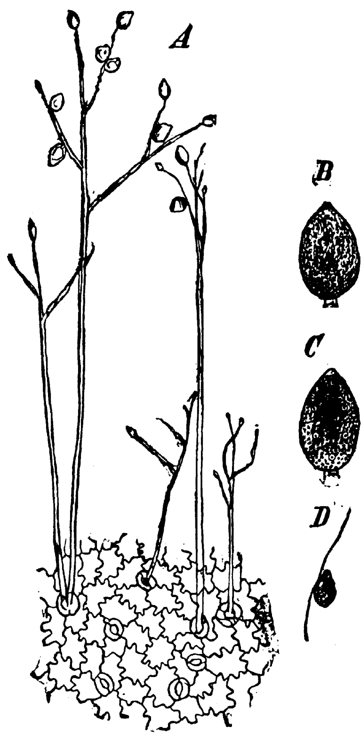


FIG. 36. POTATO DISEASE (*Phytophthora infestans*), enlarged to various scales.

A, lower epidermis of potato leaf, with conidia-bearing aerial hyphæ protruding from stomata; *B*, a conidium; *C*, ditto with dividing contents; *D*, a zoospore.

Wheat Smut (*U. tritici*) and **Barley Smuts** (*U. nuda* and *U. tecta*) closely resemble the smut of oats, but their germinating spores are believed to attack the young flowers of wheat and barley, and not the seedlings, so that pickling is of no use.

Bunt (*Tilletia caries*) is a parasitic fungus that attacks wheat and barley, in the way described for oat smut.

Here, however, the grains are allowed to develop to a certain extent, but are then riddled by mycelium, their contents being ultimately replaced by a greasy brownish mass of spores smelling like stinking fish. Pickling the grain is resorted to as a preventive measure.

Potato Disease (*Phytophthora infestans*) (Fig. 36).—The delicate mycelium of this notorious pest ramifies throughout all parts of the potato plant causing wholesale destruction of the crop. It can easily be recognized by the presence of brownish spots with whitish margins on the under sides of the leaves. Microscopic examination of the edge of such a spot will show branching aerial hyphae projecting from the stomata, and bearing egg-shaped asexual **spores** which are disseminated by air currents and rapidly spread the disease. These spores sometimes germinate directly upon leaves, protruding hyphae which penetrate the epidermis or make their way through stomata, to give rise to a mycelium. Most of them, however, undergo a further change, the protoplasm dividing into a number of motile **zoospores**, which are liberated by the rupture of the surrounding membrane. The zoospore is an ovoid cell from one side of which project two excessively delicate threads of protoplasm (flagella). These threads execute lashing movements, enabling the spores to swim about in the film of moisture that usually covers the potato plant, while some of them may be washed down into the soil and reach the surface of the young tubers. After a short time they come to rest, draw in the flagella, develop delicate cell-walls and then germinate, their hyphae entering stomata or piercing epidermal cells. The latter process is rendered possible by the secretion of a ferment that softens the cell-walls.

The mycelium of the potato disease fungus can remain in a dormant state in dead plants, or even in apparently sound tubers. It follows that all refuse from an infected crop should be burnt, and none of the tubers should be used as seed. Spraying early in the season has been found a very effective preventive measure. Bordeaux mixture is

one of the best preparations for the purpose. It is made by dissolving 12 lbs. of copper sulphate (blue-stone) in 75 to 100 gals. of water, and stirring in 8 lbs. of fresh quicklime. The quantity used is from 100 to 150 gals. per acre. Some varieties of potato are particularly susceptible to the disease, while others are more or less resistent, and it is obvious the latter should be selected if possible.

White Rust (*Cystopus candidus*).—This is a common pest of cruciferous plants, cultivated—as turnip and cabbage—or wild, like shepherd's purse. Its presence is indicated in the latter by white streaks and thickenings, and in severe cases the stems may be twisted and contorted. Infected varieties of the cabbage tribe often display elongated pustules on the under sides of the leaves, arranged concentrically. The mycelium ramifies between the cells of the host, giving off at intervals short branches with rounded ends (haustoria) which penetrate into the living cells and absorb nourishment from them.

Enormous numbers of asexual **spores** are formed during spring and summer at the surface of the host. The white blisters rupture, and from them protrude aerial hyphae, at the tips of which chains of these spores are formed. Within each spore a number of **zoospores** are developed, much like those described for potato disease (p. 94). These swarm over the host, and germinate after coming to rest, protruding hyphae that enter stomata, though it is asserted that no further development takes place unless the leaves attacked are young and tender.

Asexual propagation ceases on the approach of autumn, and resting spores are formed by **sexual reproduction** which takes place within the host, not on the surface. The female organ (oogonium) a rounded structure containing a single egg-cell, is the swollen tip of a hypha, cut off by formation of a transverse cell-wall. The male organ, **antheridium**, is formed in a similar way, but is much smaller and somewhat club-shaped. A narrow tube grows from the antheridium through the wall of the oogonium to reach the egg-cell, which is fertilized much as described for a flowering plant

(p. 37). The fertilized egg-cell (**oospore**), becomes surrounded by a thick rough coat and remains in a dormant state throughout the winter. When vegetation begins to resume growth in the following spring the contents of the oospore divide into a large number of **zoospores**, which escape by rupture of the hard protective coating and spread infection among young cruciferous plants.

The obvious preventive measures are to avoid continuous cropping, burn the refuse from diseased plants, and

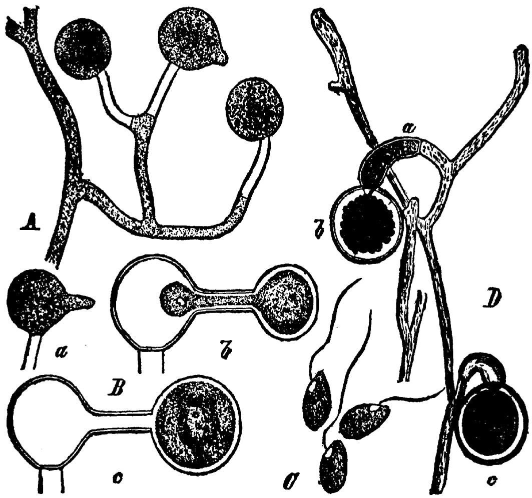


FIG. 37. DAMPING-OFF FUNGUS (*Pythium de baryanum*), enlarged to various scales
A, Mycelium bearing young sporangia; *B*, germination of a sporangium and development of zoospores; *C*, zoospores; *D*, hypha with sexual reproductive organs; *a*, antheridium; *b*, oogonium; *c*, oospore.

eradicate cruciferous weeds such as shepherd's purse, by which the pest is harboured.

Damping-off Fungus (*Pythium de baryanum*) (Fig. 37).—This and allied species cause considerable mortality among the seedlings of various cruciferous plants, white clover, spurrey, maize, and millet, especially when these are crowded together in an atmosphere saturated with

moisture, as is often the case with mustard and cress raised for small salad. The part of the stem just above the ground is first attacked, and so weakened that the seedlings topple over and speedily die, or are 'damped off.' The mycelium of the parasite branches copiously within the body of the host, and some hyphae make their way to the surface, where asexual spores and also oospores are formed. The former arise as rounded swellings at the tips of hyphae. Some of them become detached and germinate directly on damp leaves or stems, the hyphae protruding from them boring into the underlying tissues. Other asexual spores undergo further development. A beak-like projection grows out from the side, and swells up into a rounded knob, into which the protoplasm of the spore passes, afterwards dividing into ten **zoospores.** These escape and spread the disease to other plants.

The **oospores** are produced sexually much in the same way as those of white rust (cp. pp. 95-6). They drop into the underlying soil, where they may remain dormant for a long time, ultimately germinating with protrusion of a hypha that may make its way into a new victim. It is obvious that soil upon which diseased plants have grown should not be used for a fresh crop, unless a long interval elapses or there has been very thorough disinfection.

HIGHER TRUE FUNGI (*Mycomycetes*).—Transverse partitions or septa are developed at regular intervals in the hyphae of these forms, thus dividing them into a series of cells. Higher Fungi include three great groups:—(1) **Rusts** (Uredineae); (2) **Flask Fungi** (Ascomycetes); and (3) **Toadstools** (Basidiomycetes). The two first are of considerable agricultural importance.

Rusts (Uredineae) are very serious pests devastating several of our cereal crops, and deriving their name from the rusty-looking streaks and patches on the leaves and stems of infected plants, that reveal their presence in one stage of what may be, in some species, a complicated life-history.

Black Rust (*Puccinia graminis*) (Fig. 38).—This fungus, like a great many parasitic plants and animals, lives within more than one kind of host in the course of its life-history. There are two successive hosts, (1) wheat (barley, oat, or a

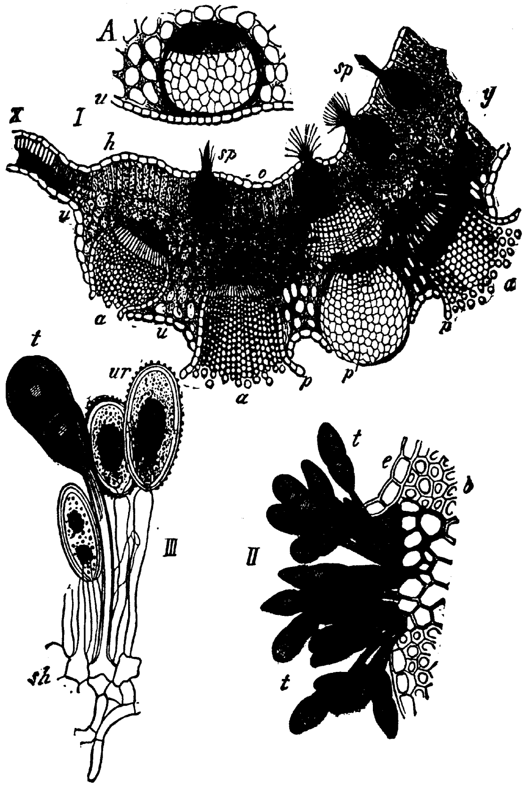


FIG. 38. BLACK RUST (*Puccinia graminis*), enlarged to various scales
I.—Cross section of infected Barberry leaf: *o*, upper; *u*, under surface; *a*, aecidia; *p*, wall of ditto; *sp*, spermogonia; at *X* natural thickness of leaf shown, infected area *u* to *y* much thickened; *A*, a young aecidinus. *II.*—Winter spores (*tt*) in wheat. *III.*—Three summer spores (*ur*) and a winter spore (*t*) on ditto.

grass); (2) barberry. Upon the leaves and stems of young wheat-plants orange-coloured streaks can often be seen,

which are the spore-producing part of the mycelium ramifying in the internal tissues. Microscopic examination of such a streak shows that the epidermis is ruptured, and that the orange colour is caused by the presence of innumerable asexual **summer-spores** (uredospores), which are blown from plant to plant and spread the disease, for they germinate and protrude hyphae that enter stomata and branch to form the mycelia of fresh rust-plants. Later in summer the disease patches change their colour to black, owing to the formation of asexual **winter-spores** (teleutospores), which are stalked like the summer-spores, but differ from them in being two-celled. They do not infect other wheat-plants, but remain in a resting state through the winter in stubble and straw. Early the following spring they germinate, each of the two cells giving rise to a short hypha (promycelium), which produces a small number of rounded asexual spores (sporidia). These can develop further and give rise to the final stage in the life-history of the parasite if transferred by the wind or other agent to the leaves of barberry. Here they germinate, the protruding hyphae penetrating the epidermal cells of the leaf by ferment action (cp. p. 94). Mycelium is then produced in the tissues of the leaf, which thickens here and there, groups of rounded spots (' cluster cups ' or **aecidia**) ultimately making their appearance on the under side. Rows of yellow rounded **aecidiospores** are produced in each cup, and are liberated by rupture of the epidermis. They cannot germinate on the barberry, but are able to infect wheat, and bring us back again to the stage in the life-history from which we started.

Small yellow spots, **spermogonia**, are also to be found on the upper sides of barberry leaves, which are regarded as male organs, though they would appear to be degenerate, for they are not known to take any part in the formation of aecidiospores, though these were probably the result of a sexual process in ancestral forms.

Black rust not only illustrates the complicated life-history of certain parasites, but also the enormous number of reproductive cells, in this case spores, that are necessary to secure

survival, for the chance of any one of them germinating under favourable circumstances is very remote. In dealing with such pests there are several means of attack, but it is obviously best to select the weakest link in the chain. In this particular case extermination of barberry, the final host, appears to be the most obvious line. Unfortunately, however, parasites are often able to adapt themselves to circumstances. The barberry not being native to Australia it might be supposed that black rust would find no foothold there. This, however, is far from being the case, for both the aecidiospore and teleutospore stages have dropped out of the life-history in that country, propagation taking place solely by the uredospores, which have acquired the power of remaining dormant so as to be able to carry on infection from one crop to another.

Yellow Rust (*Puccinia glumarum*).—This pest of wheat, barley, and rye, lives within one kind of host only, and propagates by means of uredospores, which are paler in colour than those of black rust. It is the ' spring rust ' of farmers, so called from its early appearance, which is due to the germination of uredospores that have remained in a resting condition during the winter.

Probably the best means of combating rusts, the damage caused by which is enormous, is the selection of cereal varieties which are more or less resistent to attack. Biffen has succeeded in breeding ' rust proof ' wheats by selective methods, but how long these will remain immune against attack has yet to be determined.

Flask Fungi (Ascomycetes).—In these forms a number of motionless spores (usually eight) are produced within a special cell known as an **ascus** (Gk. *askos*, bag or flask), numerous asci being associated together. In some cases they are developed as the result of a sexual process.

Ergot (*Claviceps purpurea*) (Fig. 39).—This is a parasite infesting rye and various grasses. It makes its appearance in the flowers at the base of the ovary, in the form of an investment of hyphae arising from mycelium within the tissues of the host. A vast number of minute rounded

asexual spores are budded off; and a sweet fluid (' honeydew ') is exuded that attracts flies. These visitors carry the spores to other flowers and thus spread the infection. As the season advances dark spur-like bodies, **ergots**, consisting of compacted mycelium, make their

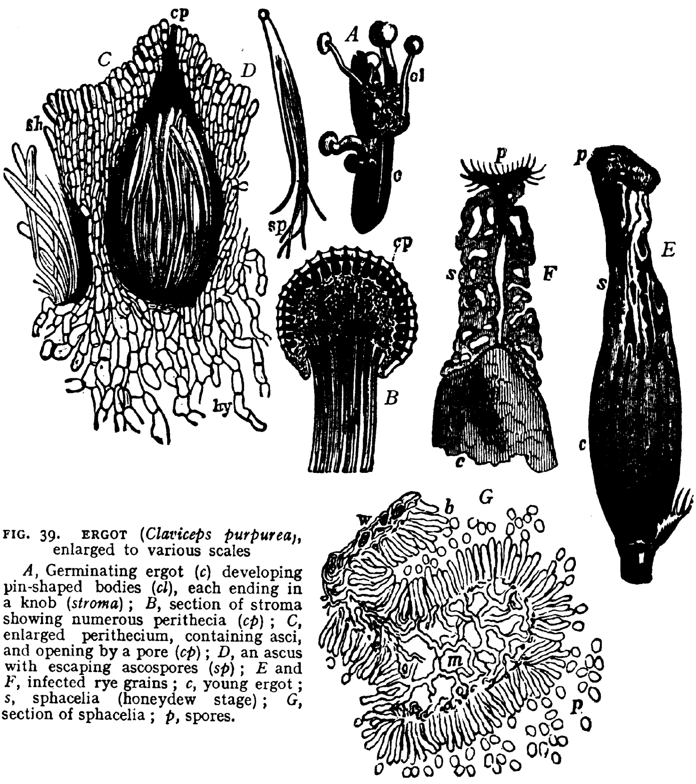


FIG. 39. ERGOT (*Claviceps purpurea*), enlarged to various scales

A, Germinating ergot (*c*) developing pin-shaped bodies (*cl*), each ending in a knob (*stroma*); *B*, section of stroma showing numerous perithecia (*cp*); *C*, enlarged perithecium, containing asci, and opening by a pore (*cp*); *D*, an ascus with escaping ascospores (*sp*); *E* and *F*, infected rye grains; *c*, young ergot; *s*, sphacelia (honeydew stage); *G*, section of sphacelia; *p*, spores.

appearance, ultimately falling to the ground and remaining in a dormant state throughout the winter. Germination takes place the following spring, when a number of stalked purple knobs grow out from the ergot. On the surface of each knob (stroma) are a number of small pores, each of

which is the opening of a cavity (perithecium) containing a number of club-shaped **asci**. Eight thread-like **ascospores** are developed in each ascus, ultimately making their escape to the exterior, when they are disseminated by the slightest breath of air. At this time the host-plants are coming into flower, and should one of the slender spores reach the base of an ovary it germinates to give rise to the mycelium first mentioned.

This pest is not only detrimental to the rye crop, but the ergots are dangerous to stock, for they may lead to abortion if eaten by pregnant cows or ewes. Ergoted grasses should be collected and destroyed, and care should be taken lest ergots are inadvertently sown either in the case of rye or of cultivated grasses, especially the rye-grasses.

Green Mould (*Pencillium glaucum*).—This is a very common saprophyte, growing on various articles of food, including certain kinds of cheese, where it helps to impart a special flavour. Strings of asexual spores are budded off from the branches of aerial hyphae.

Blue Mould (*Aspergillus glaucus*).—This is another saprophytic fungus found on cheese. The fertile hyphae are swollen at their tips, that are studded with peg-like projections from which rows of asexual spores are budded off.

Toadstools (Basidiomycetes).—These are of no agricultural importance, so do not require detailed description. Most of them are saprophytes, but some are parasitic upon trees. A familiar example of the former is the **mushroom** (*Agaricus campestris*), of which the mycelium ('spawn') ramifies in the soil. The part seen above ground is an arrangement for producing asexual spores. On the under side of the expanded top there are a number of radiating plates or 'gills,' which are pink when young, afterwards becoming brown and finally black. A section through one of these plates shows it to be covered with elongated cells, from each of which four basidiospores are produced.

CHAPTER VI

CLASSIFICATION OF PLANTS—THALLOPHYTA—FALSE FUNGI—YEASTS AND BACTERIA

FALSE Fungi include a great number of microscopic forms, which are typically unicellular, i.e. the body consists of a single cell. They are divided into the two groups of Yeasts and Bacteria.

YEASTS (Saccharomycetes) (Fig. 40).—A well-known

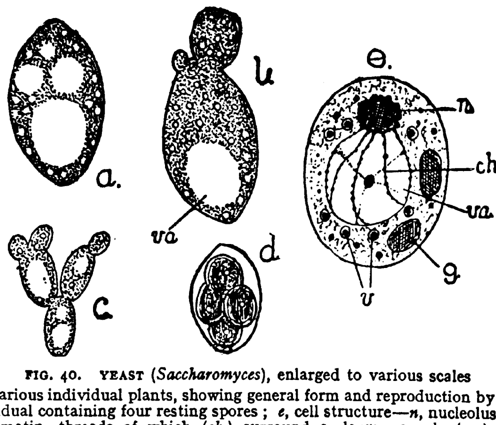


FIG. 40. YEAST (*Saccharomyces*), enlarged to various scales
a–c, various individual plants, showing general form and reproduction by budding; *d*, individual containing four resting spores; *e*, cell structure—*n*, nucleolus, invested by chromatin, threads of which (*ch.*) surround a large vacuole (*va.*), *g* and *v*, reserve materials. (The nucleolus, together with the vacuole and its chromatin investment, probably represent a nucleus).

type of **yeast-plant** (*Saccharomyces cerevisiae*) can be obtained for examination in the form of brewers' yeast or the compressed yeast-cakes used by bakers. Either of these materials if subjected to microscopic examination will be found to contain myriads of spherical or ovoid cells,

each of which is a distinct plant. Asexual reproduction takes place by means of **budding**, which is a process of overgrowth, where a projection bulges out from a parent cell and is gradually pinched off. The economic interest of yeast plants consists in the alcoholic fermentation they set up in solutions containing sugar. This is split up with formation of alcohol and liberation of carbon dioxide, and the promotion and regulation of this process is the most important part of the manufacture of beer, cider, and wine.

Under unfavourable conditions the protoplasm of a yeast plant is able to divide into four asexual **spores**, which remain dormant until germination becomes possible by changes in the surroundings.

BACTERIA (Schizomycetes) (Fig. 41).—These unicellular

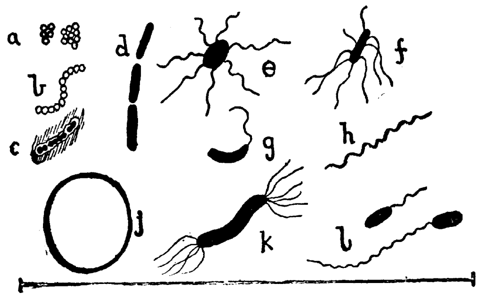


FIG. 41. VARIOUS BACTERIA, X 1000 (approximately)

a, *Staphylococcus aureus*; *b*, *Streptococcus pyogenes*; *c*, *Pneumococcus* (cause of pneumonia); *d*, *Bacillus anthracis* (cause of anthrax); *e*, *Bacillus typhosus* (cause of typhoid fever); *f*, *Bacillus tetani* (cause of tetanus); *g*, *Microspora comma* (cause of cholera); *h*, *Spirillum* of relapsing fever (*S. rubrum*); *l*, *Pseudomonas*; the wavy lines in *e*, *f*, *g*, *k*, *l* represent flagella; *j*, a red blood corpuscle on same scale, and line below the breadth of a fine human hair, about half the thickness of a sheet of newspaper.

fungi are the smallest existing plants, and some of them are only just visible under the highest powers of the microscope, while there are others of which the existence is only inferred. They are to be found practically everywhere in enormous numbers, their presence being associated with many common phenomena that are of great interest and importance, such as putrefaction, preparation of plant food in the soil, infectious and contagious diseases, and dairy processes, e.g. the 'ripening' of cream. Many of them have

been called with justice 'the invisible friends and foes of the farmer.'

Bacteria differ in shape, and this may vary in the course of the life-history. The spherical form is known as a **coccus** or, if exceedingly small, a **micrococcus**. A short stout rod is a **bacterium**, a slender one a **bacillus**, and a spiral rod a **spirillum**. The diameter of a coccus does not usually exceed $\frac{1}{25000}$ of an inch, while rods vary from $\frac{1}{6000}$ to $\frac{1}{12000}$ of an inch in breadth, and are from twice to five times as long as broad.

The typical method of reproduction is by means of transverse splitting or **fission**, and under favourable conditions this may take place with great rapidity. It has been calculated that a single individual is capable of giving rise to 17 million offspring in twenty-four hours. Remembering the minute size and enormous fecundity of bacteria we are able to understand why disinfection of stables, cow-sheds, and pigsties, must be carried out with the utmost thoroughness after there has been an outbreak of contagious or infectious disease. To leave even the smallest spots or crevices untreated is simply to invite further trouble. Yet farmers and others have been known to discredit the existence of bacteria because they are not visible to the naked eye. Bacteria are able to tide over unfavourable periods by the formation of inconceivably minute hard-coated **spores** (Fig. 41A), which are blown about like dust from place to place, and germinate wherever they find suitable spots. A notable case is that of the bacillus causing consumption (tuberculosis). If a consumptive person spits on the pavement, the 'spit' (sputum) dries up, and the innumerable bacilli present at once form spores, which easily spread the infection.

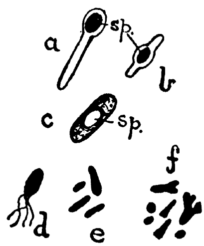


FIG. 41A. BACTERIA (much enlarged)

a–c, Formation of spores (*sp.*); *a*, *Bacillus tetani*; *b*, Bacillus of malignant oedema; *c*, *Bacillus oedamitis*; *d–f*, Nitrogen-fixing bacteria; *d*, *Azotobacter*; *e*, *Clostridium; pasteurianum*, *f*, *Pseudomonas radicico la.*

Bacteria of The Soil (Fig. 42).—The dark part or **humus** (p. 13) of the soil swarms with various kinds of bacteria that live, as saprophytes, on complex organic substances, gradually transforming them, by ferment action, into nitrates which are available as the food of crops. Three groups of bacteria are concerned with this work:—(*a*) **Ammonifying bacteria**, converting nitrogenous matter into *ammonia compounds*. Among these are included the bacteria causing putrefaction. (*b*) **'Nitrite' bacteria**, which

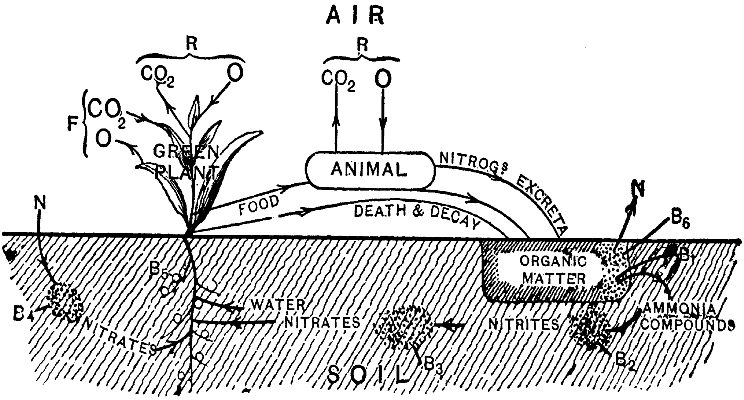


FIG. 42. SOIL NITROGEN

Both green plants and animal take in oxygen (O) and give out carbon dioxide (CO_2) in course of respiration (R). The animal feeds on plants, and by nitrogenous excretion and ultimate death adds to the store of organic matter in the soil. The green plant in the course of feeding (F) takes in carbon dioxide (CO_2) from the air, returning oxygen (O), and also takes up plant food from the soil; its dead parts contribute to the store of organic matter in the soil. The groups of bacteria B_1, B_2, and B_3, respectively produce ammonia compounds, convert these into nitrites, and these again into nitrates. The free bacteria (B_4) and the nodule bacteria (B_5) fix the free nitrogen of the air (N, to left) with production of nitrates. The bacteria (B_6), in the absence of oxygen, decompose organic matter with liberation of free nitrogen (N, to right).

convert ammonia compounds into *nitrites*. (*c*) **'Nitrate' bacteria**, that convert nitrites into *nitrates*. The groups (*b*) and (*c*) are together known as **'nitrifying' bacteria**. Among nitrite bacteria is included the widely distributed *Nitrosomonas*, occurring in the form of motile rods 1·2 to to 1·8μ long by 0·9 to 1·9μ broad. Typical nitrate bacteria

are species ~~of~~ *Nitrobacter*, non-motile rods 1·0μ long by 0·3 to 0·4μ broad.[1]

There are also two kinds of bacteria which ' fix ' the free nitrogen of the air circulating in the soil, with formation of nitrates. They include (*a*) bacteria (*Azotobacter*) which live in the soil itself, and (*b*) bacteria (*Pseudomonas radicicola*) that inhabit swellings or nodules on the roots of leguminous plants. The latter are a good example of **symbiosis**, where two different organisms are intimately associated together to the benefit of both. The bacteria, when they die, are absorbed as nitrogenous food by the leguminous plant within which they dwell; during their life they depend on this for a supply of ready-made carbon compounds. All the preceding bacteria are **aerobic**, i.e. they are unable to flourish without oxygen provided by free access of air. But humus also contains **anaerobic** forms, which cannot grow and flourish properly if free oxygen be present. Such are the **' denitrifying ' bacteria**, that break up organic matter with liberation of oxides of nitrogen or free nitrogen.

Since denitrification involves the loss of valuable nitrates, it is undesirable from the farmer's point of view and should be checked as much as possible, Badly drained soils are deficient in free oxygen, air being more or less excluded, and this favours the work of denitrifying bacteria. Proper drainage is the obvious means of checking or entirely stopping their action.

Heaps of manure or compost contain innumerable bacteria, including ammonifying and denitrifying species. When such a heap is loosely made, so as to permit the free circulation of air, the formation of nitrates goes on steadily. If now the heap is drenched with rain, denitrifying bacteria are able to get to work, with the result that the nitrates are broken up and dissipated. It therefore follows that overhead shelter should be provided for such heaps, and that the common practice of watering them results in a loss of valuable material.

[1] The symbol μ, used in describing extremely small objects, 1/1,000 of a millimetre, i.e. approximately 1/25,000 of an inch.

Partial Sterilization of Soil.—If soil is partially sterilized either by heat or by the application of chemical substances (carbon disulphide (CS_2), toluene, etc.) its fertility is first diminished and then very rapidly increases. The researches of Russell and Hutchinson at Rothamsted render it probable that the relations between desirable bacteria and the innumerable microscopic animals (Protozoa) that swarm in the soil furnish an explanation of the facts. These Protozoa apparently prey on the bacteria (nitrifying and nitrogen-fixing forms), thus limiting their activities and preventing a large increase in nitrates. The application of heat or an antiseptic kills the Protozoa, ridding the friendly bacteria of their enemies. But at the same time it kills the bacteria, so that a loss of fertility immediately ensues. The spores of the bacteria, however, survive the treatment, germinate, and multiply with great rapidity, raising the fertility above the normal level.

Bacteria and Milk.—A drop of milk if looked at through the microscope will be found to contain innumerable fat globules suspended in liquid. The latter contains milk, sugar, and proteins. Milk may be described as a natural emulsion, and results from the breaking down of the cells lining the minute tubes making up the greater part of the udder. It is an ideal medium for the growth and multiplication of innumerable bacteria, desirable and otherwise. The numbers of the latter can only be kept down by the most scrupulous cleanliness, and even then the milk is exposed to bacterial invasion many times over before it reaches the consumer.

By keeping the milk at a low temperature, 50°F. or less, these almost inevitable bacteria are prevented from rapid increase, while on the other hand they can be entirely or partly destroyed by the application of sufficient heat. **Sterilization,** which kills all the bacteria, can be effected by boiling the milk for twenty minutes on three or four successive days, or by raising it to a still higher temperature under pressure, when one treatment suffices. This process, however, impairs the flavour and renders the

milk less digestible. It also destroys the vitamines (p. 47). **Pasteurization** is a compromise by which many bacteria are killed, these fortunately including disease-producing forms. The milk, or cream, is raised to a temperature of about 150°F. for twenty minutes, and then quickly cooled to about 60°F.

Souring or Ripening of Cream.—Before cream can be converted into butter it must be allowed to 'ripen,' i.e. to develop a certain amount of acidity or sourness as the result of fermentation. The cream itself contains an unorganized ferment, **lactase**, that converts the milk sugar into two other kinds of sugar—glucose and galactose—the latter being acted upon by certain bacteria with production of lactic acid. In the case of milk that has become sour the acid curdles or clots the caseinogen, with formations of casein. A number of different kinds of bacteria are able to effect this lactic fermentation, but of these the commonest and most typical is *Streptococcus lacticus*, comparable in appearance to a necklace of slightly oval beads, each 0·5 to 1·0μ long. The process is accelerated by the addition of **starters** containing the desired bacteria. A 'natural starter' consists of a little buttermilk or sour milk, while an 'artificial starter' is a laboratory culture of bacteria. By using the latter with pasteurized cream it is possible to secure a butter of uniform quality, a matter of great commercial importance, but the same certainty does not attend the use of natural starters unless absolute cleanliness is secured by the most rigid precautions.

Milk Faults and Bacteria.—As a result of the presence of various undesirable bacteria, milk may be slimy, of abnormal colour (red, blue, yellow), or unpleasantly flavoured. More serious still, it may serve as a means of spreading tuberculosis, typhoid fever, diphtheria, scarlet fever, and other diseases. Most of these faults are due to dirt, but the presence of the bacilli causing tuberculosis points to diseased cows as one source of infection.

Butter and Cheese Bacteria.—Both desirable and undesirable odours and flavours in butter and cheese are,

to a large extent, the result of bacterial fermentations. The subject is one of great complexity, and a great deal of research is necessary before we can automatically control the course of events so as to ensure, for example, that Stilton cheese shall be of uniform quality.

Bacteria and Disease.—Most infectious and contagious diseases of animals are caused by bacteria, some of which are also responsible for certain diseases of plants. It is convenient to begin with the latter.

White Rot of Turnips (*Pseudomonas destructans*).—The first symptoms of this disease are exhibited by the leaves, which fade and become yellow in colour. After this the roots are attacked and ultimately become a soft white decomposing mass that is washed into the soil by rain. Microscopic examination shows the presence of innumerable bacteria, in the form of short rods, each provided with a flagellum, i.e. a slender thread of protoplasm executing lashing movements, that enables the parasite to swim about. These pests produce a poison (oxalic acid) that kills the living substance of the host, and they also manufacture a ferment by which the firm cell-walls are dissolved. The bacteria are able to live for a long time as saprophytes on the decaying organic matter in the soil, so that they can tide over the interval between successive crops. The turnip is not the only host, potatoes and carrots being also attacked.

Brown Rot of Cabbage (*Pseudomonas campestris*).—This pest, closely related to white rot, attacks cabbages and other cruciferous plants, and can also live as a saprophyte in the soil. The vascular bundles (veins) of affected leaves turn brown, owing to the presence of the bacteria in their woody parts, along which they spread to stem and root, blocking up the wood-vessels and interfering with the flow of sap.

Bacterial Diseases of Animals.—As these include such scourges as tuberculosis, glanders, anthrax, and swine fever, farmers should know something about them, especially as some are 'notifiable.' But it is a mistake to suppose that the expert services of veterinary surgeons can be dispensed with in the case of serious ailments of stock

Colourless Corpuscles and Bacteria.—Some varieties of the colourless corpuscles found in blood serve as a kind of territorial army for defence of the body against disease bacteria that invade the tissues from without. They simply flow round and engulf these enemies, which are then digested by their protoplasm. In an animal or human being suffering from an infectious or contagious disease of bacterial nature there is a continuous fight between the bacteria and the defensive corpuscles, the result being recovery or death, according to the side which is victorious. This, however, is only part of the truth, for the details of this microscopic warfare are singularly complex. One factor in favour of the bacteria is the extraordinary rapidity with which they are able to multiply (p. 105) especially in such a highly nutritive fluid as blood. Their activity is associated with the production of highly poisonous waste products known as **toxins**, the increase of which beyond a certain amount is fatal to the animal attacked.

There is, fortunately, a defensive side to this chemical warfare. The blood contains certain complex substances known as **opsonins**, which stimulate the colourless corpuscles and help them to take in and digest the bacteria. These substances may be compared metaphorically to Worcestershire sauce, or to the tot of army rum served out before 'going over the top.' Besides this, the toxins are neutralized and rendered harmless by **antitoxins** formed in the blood, and these help the colourless corpuscles in their fight against the intruders.

Immunity.—An animal or human being which is not liable to 'catch' or contract a disease caused by bacteria is said to be **immune** as regards that disease, and such immunity may be complete or partial. A distinction is also drawn between natural and acquired immunity. In the former case the blood naturally contains some defensive or **anti-body** that arrests the action of certain disease bacteria, e.g. the horse is not liable to suffer from diphtheria. Acquired immunity often follows recovery from

some particular kind of infectious or contagious disease, as when a human being who has suffered from smallpox proves insusceptible to further attacks, at least for some years. In such a case it seems likely that the appropriate anti-body, which was formed in the body to combat the first attack, was produced in such quantity that enough remained for use on future occasions.

Immunity may also be acquired artificially by means of **inoculation**, of which the most familiar example is vaccination against smallpox. Such artificial immunity is either **active** or **passive**. In the former case small doses of the disease bacteria (often weakened by special methods of treatment in the laboratory), either living or dead, or of the toxins produced by them, are injected into the animal to be protected. In this way the acquired anti-bodies are brought into existence in the blood of such an animal. The substance injected is termed a **vaccine**. Two diseases that can be warded off in this way are small-pox, in human beings, and anthrax, in cattle and sheep.

Passive artificial immunity of a healthy animal is brought about by inoculation with serum from a protected animal. (**Serum** is the liquid part of coagulated blood.)

Serum treatment may also be resorted to, in certain cases, in order to **cure** an animal (or human being) that has already contracted the particular disease. Two particularly deadly ailments, diphtheria and tetanus (lockjaw), if taken in an early stage, can be cured in this way.

The whole question of inoculation is one of extreme difficulty and complication, and it is out of the question to give details here, but the methods briefly indicated above have already proved extremely valuable, both for preventive and curative purposes, and they appear to be capable of almost unlimited extension.

It remains to be stated that some vaccines have found a use in the **detection** of disease. The two best-known preparations of the kind are **tuberculin** and **mallein**, by which the presence of tuberculosis and glanders, respectively, can be demonstrated with considerable accuracy.

CHAPTER VII

GEOLOGY—MINERALS, ROCKS, GEOLOGICAL AGENTS, THE GEOLOGICAL RECORD

A BRIEF account of the nature and structure of Soil has already been given (p. 9), but the subject is of such primary importance to the farmer that a wider survey will now be taken, commencing with an outline of **Geology**.

This important branch of natural science is concerned with the unwritten history of the earth from the time when it was a glowing molten mass to the present day. The process of cooling gave rise to a firm outer part, the **crust**, which has since undergone a vast amount of change, and is still being incessantly modified by the action of a large number of forces; the surface soils, for example, being continually altered in character. Oceans and seas occupy hollows in the crust, while its projecting portions constitute the land. In this, however, there are some hollows below sea level. The surface of the Caspian Sea, for example, is 84 feet, and that of the Dead Sea 1,298 feet below the surface of the Mediterranean.

MINERALS.—These are substances with definite chemical and physical characters, not directly derived from plant or animal sources, and the components of rocks and soils. One physical character typical of most minerals is their tendency to assume the form of crystals. If, for example, a saturated solution of common salt is allowed to evaporate, the residue will be found to consist of minute transparent cubes composed of the salt which has been left behind. Each of these is a **crystal**, i.e. a solid of definite geometrical form bounded by flat faces that meet together in straight

edges. (In a few cases the faces are curved.) Almost all minerals are able to assume the crystalline form, and a particular mineral can be recognized by the shape of its crystals.

Many minerals **cleave**, or split up in one or more definite directions, and this aids materially the process of disintegration by which soils are formed.

Many thousands of different minerals have been described but only a few are of agricultural importance, and a brief account of these will serve our present purpose.

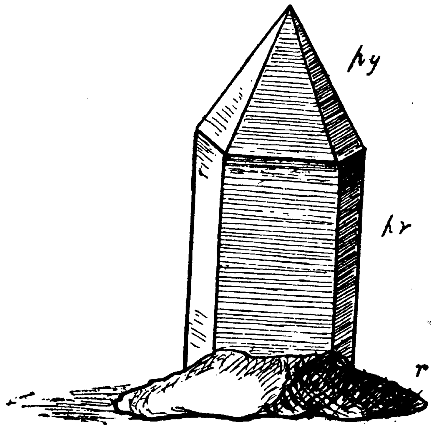


FIG. 43. QUARTZ CRYSTAL, attached to a piece of rock (*r*) *pr*, Hexagonal prism; *py*, hexagonal pyramid.

Silica (L. *silex*, flint) is perhaps the commonest of all minerals, being the typical constituent of sandstone, sand, and sandy soils. Chemically it is oxide of silicon ($Si\ O_2$), and when crystallized is known as **quartz** or **rock crystal**, which is found in six-sided prisms, with a six-sided pyramid at one or both ends (Fig. 43). It is transparent, extremely hard, and does not cleave. Impure uncrystallized silica makes up the familiar substances called flint and chert, which occur in layers and nodules in limestones

and sandstones. The term **flint** is restricted to masses of the kind found imbedded in chalk, while similar material found elsewhere is termed **chert.** Sand and sandstone are largely composed of worn particles of quartz, while many gravels are made up of flint pebbles. As already mentioned (p. 2) silica is found as a strengthening material in some plants, especially grasses and cereals, although silicon cannot be regarded as an essential element in plant food.

Silicates are complex substances which play a very important part as rock-builders. Granite, for example, is a mixture of quartz with various silicates. They are essentially silicates of alumina combined with various other silicates, such as those of potash, soda, lime, magnesia, and iron. Here are included the **Felspars,** hard minerals comprising (*a*) *orthoclase* or potash felspar, which crystallizes in bilateral oblique prisms, and cleaves in two directions at right angles to each other; (*b*) *plagioclase,* occurring in prisms that are oblique and asymmetrical, and cleave in two directions that are not at right angles. Plagioclase is again divided into soda felspar (albite), soda-lime[1] felspar (oligoclase), lime-soda felspar (labradorite), and lime felspar (anorthite).

Micas are soft silicates crystallizing in plates that readily cleave into thin elastic flakes. **Muscovite,** potash mica, is white in colour. It is called "talc" in trade, and used instead of glass in lanterns, and slow combustion stoves with transparent panels in front; also in the smoke protectors placed over lamps. **Biotite,** magnesia mica, is black. Glittering flakes of white mica are seen in many sandstones.

Carbonates are of great agricultural importance, because they enter largely into the composition of limestones. **Carbonate of lime,** the commonest of these, is often found in crystals which are not unlike those of quartz, but are easily distinguished by the fact that they are easily

[1] Soda-lime means containing more soda than lime, and lime-soda has the contrary meaning.

scratched with a knife, and are readily dissolved by dilute hydrochloric acid, 'fizzling up' owing to the liberation of bubbles of carbon dioxide. They cleave very perfectly in three directions. When crystallized this carbonate is known as **calcite** (calc spar) and **aragonite**. In some limestones, such as white statuary marble, it is finely crystalline, while in others, e.g. chalk, it is granular. The 'lime' applied to the soil by farmers is obtained by heating limestone in a kiln, when carbon dioxide is driven off, leaving behind finely divided **quicklime** or oxide of lime (CaO). Exposed to the action of moisture this becomes **slaked lime** ($Ca(OH)_2$). Mortar is made by mixing slaked lime with water and sand, and as this dries carbon dioxide is gradually absorbed from the air, with formation of carbonate of lime, by which the grains of sand are bound together.

Dolomite is a double carbonate of lime and magnesia, which only reacts to dilute acid on the application of heat. The crystallized form is **pearl spar**, not unlike calcite, and the granular form constitutes **magnesian limestone.**

Chlorides are among the mineral substances found in deposits that have resulted from the drying-up of inland seas and salt lakes. The most familiar is **sodium chloride** ($NaCl$) or common salt, which crystallizes in cubes that can easily be scratched with the finger-nail. It is sometimes employed as a manurial top-dressing, and forms an essential part of the food of animals. **Potassium chloride** (KCl) or muriate of potash is one of the important potash manures, which when found in natural deposits is known as **sylvine.**

Sulphates also occur as minerals, the most familiar being **sulphate of lime** ($CaSO_4$), which when combined with water forms **gypsum**, a granular substance used as a top-dressing, and also ground up to make plaster of Paris. In the crystalline form, **selenite**, it is soft and transparent.

Chlorides and sulphates are associated in the extensive deposits of Stassfurt, in Saxony, the chief source of potash manures, though these are also obtained from Alsace and

Austria. The Stassfurt salts include not only rock salt, sylvine, and gypsum, but also more complex compounds, **carnallite** (chlorides of potash and magnesia), **polyhalite** (sulphates of potash, magnesia, and lime), and **kainit** (chloride of potash and sulphate of magnesia), all three containing water of combination.

Nitrates.—Chile saltpetre or nitrate of soda ($NaNO_3$), an exceedingly important nitrogenous manure, has been spoken about in a previous chapter (p. 12).

Phosphate of lime has a wide distribution in mineral deposits that are an important source of phosphatic manure. The crystallized form is **apatite**, occurring in six-sided prisms which can be scratched with a knife, though not so readily as calcite. They are often greenish or reddish-brown owing to the presence of impurities. When granular or imperfectly crystallized mineral phosphates are called **phosphorite**, which is sometimes in the form of rounded nodules, such as those which used to be extensively worked, under the name of 'coprolites,' in the neighbourhood of Cambridge. The most important deposits of phosphorite are found in North Africa, particularly in Algeria and Tunis, but others occur in France, Belgium, Germany, and Florida.

ROCKS.—These are the building materials of the earth's crust, and they consist of mixtures of minerals. Many of them, as limestone, sandstone, and granite, are firm and stony; but they also include loose materials, such as sand and clay. Sometimes a single mineral forms extensive deposits, which are then known as rocks. Rock salt and gypsum may be taken as examples.

Classification of Rocks.—It is convenient to draw a distinction between igneous, aqueous, and metamorphic rocks, according to the mode of origin. **Igneous rocks** have cooled from a state of fusion, and include the partly crystalline lavas, poured out on the surface through volcanic fissures, and completely crystalline rocks, such as granite, which have consolidated at a great depth. Comparatively recent lavas help to build up such active

volcanoes as Vesuvius and Etna, while the compact black basalt which covers a large part of Antrim may be taken as an example of an ancient lava. The original crust of the earth was of igneous nature.

Aqueous rocks, on the other hand, are built up, directly or indirectly, from materials produced by wear and tear of the land. They are described as *mechanically formed* when deposited in the sea, or to a less extent in lakes, as sand, clay, and the like. Somewhat similar mechanical deposits have also been formed on the surface of the land by the action of the wind, especially in desert regions.

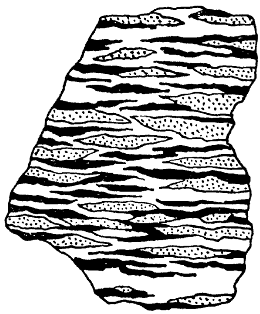


FIG. 44. PIECE OF SCHIST
Dotted part = Felspar; white part = Quartz; black part = Mica.

Certain aqueous rocks, such as the Stassfurt salt deposits, have been *chemically formed,* and may be described as precipitates on a large scale. There are also *organically formed* aqueous rocks, made up of the hard parts of plants or animals, a good example being chalk, which is mainly composed of the calcareous shells of minute Protozoa (foraminifera).

Metamorphic rocks have been derived from rocks of the two other kinds by the action of intense pressure due to movements of the crust, associated with the action of superheated water. The chemical changes set up under these conditions have altered them profoundly. The **schists** (Fig. 44) that make up a large part of the Scottish Highlands are of this nature, their distinctive feature being **foliation**, i.e. the arrangement of their component minerals in little crumpled plates, **folia** (L. *folium,* a leaf), suggestive of leaves.

ORIGIN OF AQUEOUS ROCKS.—The materials of which

aqueous rocks are composed have been derived from pre-existing rocks by the mechanical and chemical action of a number of **disintegrating** agents, the most important being—changes of temperature, air, atmospheric water, underground water, rivers, ice, and the sea. The various products of wear are carried away or **transported**, and ultimately **deposited** in water, mostly in the sea, or to a less extent in lakes and on land. They are either in the solid form, like sand and mud, or in solution. Mechanically formed rocks result from accumulation of the former, while dissolved substances supply the material from which chemically and organically formed rocks are built up.

AGENTS OF DISINTEGRATION.—These are of particular importance in agriculture, because they not only provide the materials for building up aqueous rocks but are also concerned with the production of soils.

(1) **Changes of temperature** help to break down rocks, especially in hot climates where the nights are much colder than the days. But even in temperate countries they are not unimportant, and are particularly effective in the case of such a rock as granite, which consists of three different minerals—quartz, felspar, and mica. When heated or chilled these expand or contract to a varying extent, the result being that a good deal of cracking takes place.

(2) **Air,** when in motion as wind, wears away rocks mechanically, partly by removal of loose particles, and partly by blowing sand over exposed surfaces, which are thus gradually worn down. It also exerts a chemical action, oxidizing such minerals as those which contain iron compounds, and dissolving others by its contained moisture charged with carbon dioxide.

(3) **Atmospheric water** includes rain, frost, hail, sleet, and snow, the two first of these being far the most important. Rain acts mechanically by washing away loose material, especially on sloping ground, while its chemical action resembles that of air, but is much more active. Limestone and other calcareous rocks are particularly liable to be attacked.

Frost is a very potent mechanical agent of disintegration, its action resulting from the expansion water undergoes on freezing, and which is practically illustrated by the bursting of water pipes in winter. In similar fashion rocks and clods which have been saturated with water are shattered when this freezes (cp. p. 10).

The combined action of changes of temperature, air, and atmospheric water is conveniently described as 'weathering.'

(4) **Underground water.**—Part of the rain that falls on the ground evaporates into the air, and another part runs off on the surface to augment some brook or stream, but a considerable portion sinks into the ground and becomes underground water. This moves through a complicated set of cracks and larger spaces that make up a subterranean

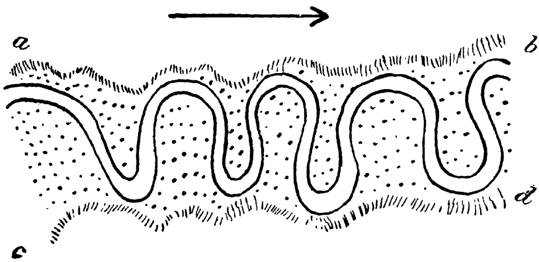


FIG. 45. MEANDERS OF STREAM

ab, *cd* = Margins of meander belt. Dotted part is alluvium. Direction of flow indicated by arrow.

drainage system, and part of it emerges again in **springs**, an important source of rivers.

Underground water acts chemically on the rocks through which it travels, and the caverns in limestone districts are a striking example of its disintegrating power.

(5) **Rivers** are mechanical agents for the most part, excavating and deepening their own valleys. This action is greatly accelerated, especially in flood time, by sand and other loose materials swept along in suspension or, in the case of larger fragments, rolled along the bottom. A river deepens its valley by cutting downwards like a

vertical saw, but broadening goes on at the same time, in a manner comparable to the action of a horizontal saw. The latter process is particularly well seen where a river pursues a winding course (Fig. 45), a very common occurrence, and in any particular bend it will be found that on the concave side, where the current is strongest, the bank is gradually under-cut, while on the convex side gravel and sand are deposited. In this way a river continually alters its course where its valley is wide, wandering about from side to side and slicing away horizontally, so that in course of time the whole of the valley floor is reduced to a lower and lower level.

(6) **Ice.**—Here are included glaciers, ice-sheets, and icebergs. **Glaciers** may popularly be described as rivers of ice, slowly creeping down valleys from a central snow-field, and melting at the snow-line (Fig. 46). They round off, grind, and polish underlying surfaces, this mechanical action being intensified by fragments of rock frozen into their under surfaces, and the loose materials dragged along below them. Many rivers, such as the Rhine and Rhone, take origin from melting glaciers, and are very turbid at their source, owing to the presence of fine mud produced by the grinding action of the ice.

Ice Sheets are thick masses of ice which are not limited to valleys but cover continuous land surfaces, as in the Antarctic continent and central Greenland. They are in slow movement, like glaciers, and their action is similar, but on a larger scale. An ice-sheet or the glaciers arising from its margin, may stretch down into the sea, where fragments that break off float away as **icebergs**, but these are of little importance as agents of wear.

(7) **The Sea** is for the most part a mechanical agent, and cuts away the edge of the land like a horizontal saw between high and low tide-marks.

Divisional Planes in Rocks.—Disintegration by the agencies just considered is greatly facilitated by the presence in rocks not only of cracks and crevices produced by shrinkage, but also of more regular and extensive

divisional planes. **Joints** (Fig. 47) are fissures found in firm rocks of all kind, and probably due to movements of the earth's crust. In aqueous rocks such as limestones and sandstones two sets are usually present, the more important being termed master-joints. The most interesting case of jointing in igneous rocks is afforded by the **columnar structure** seen in many compact lavas, e.g. the

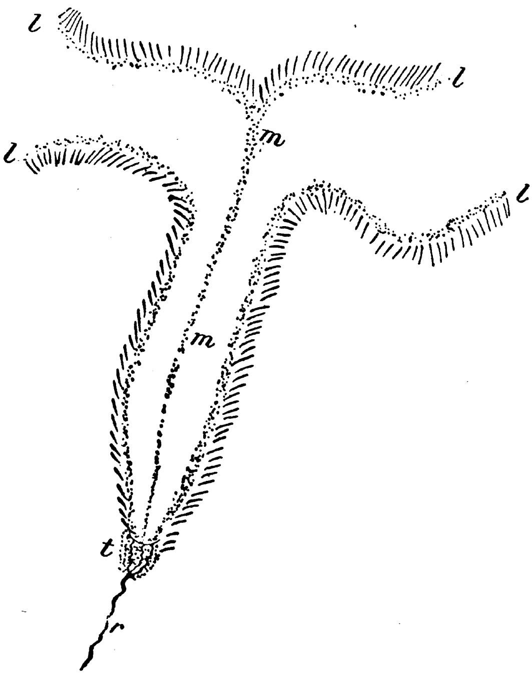


FIG. 46. PLAN OF GLACIER

Slopes of hillsides indicated by oblique lines. *ll*, lateral moraine; *mm*, medial moraine; *t*, terminal moraine; *r*, river issuing from end of glacier.

basalt making up the Giant's Causeway on the coast of Antrim. This is divided into a series of long prisms, mostly six-sided, and each prism is again transversely jointed into a number of pieces.

Faults (Fig. 48) are fractures undoubtedly due to earth movements, which in this case have shifted the broken ends away from one another to a greater or less extent, from a fraction of an inch up to thousands of feet. Many important deposits of metalliferous minerals are found in such cracks.

Stratification or **Bedding** (Fig. 47) is the layered structure typical of many aqueous rocks and due to the way in which

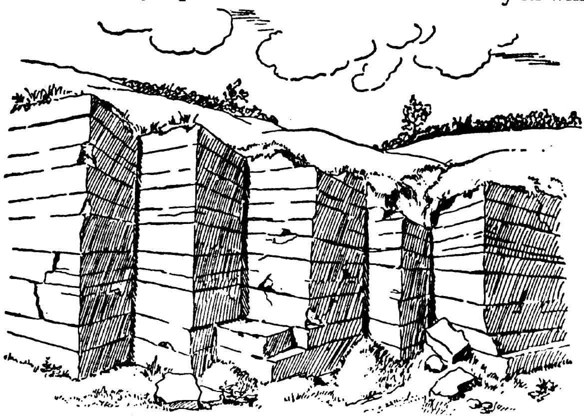


FIG. 47. QUARRY SHOWING BEDDING (STRATIFICATION) AND JOINTING
The nearly horizontal lines indicate bedding planes, and the vertical faces join planes.

they have accumulated. A single layer is known as a **stratum** or **bed**, and this, in fine-grained deposits, may again be divided into thinner layers or **laminae**. A pile of books will serve to represent a series of strata, the leaves of each book corresponding to a set of laminae.

Slaty cleavage.—Some of the fine-grained rocks, such as clays, have been exposed to extreme pressure, the result of which has been more or less to obliterate the planes of stratification and produce cleavage planes at right angles to the direction of pressure. Slate being the typical rock resulting from this process, it is convenient to speak of 'slaty' cleavage, an entirely different thing from mineral cleavage.

Foliation has already been described (p. 118), and here the divisional planes are of small extent.

AGENTS OF TRANSPORT AND DEPOSIT.—The waste of the land, partly in the solid form and partly in solution, is sooner or later carried away to be deposited at a greater or less distance from the place of origin.

(1) **Rivers** are the most important agents of transport, sweeping away vast quantities of material in mechanical suspension, rolling along larger fragments, and carrying various substances in solution. The land waste thus borne along is mostly produced by the action of weathering agents, but rivers themselves, and in some cases glaciers (p. 121), are responsible for a good deal of it. From calculations made on the transporting work of a large

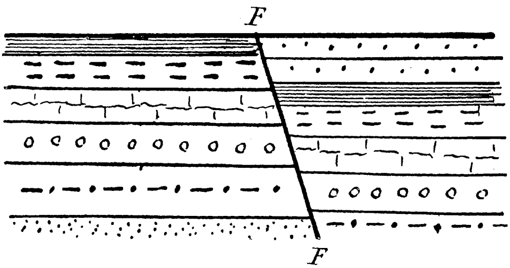


FIG. 48. VERTICAL SECTION OF FAULT
FF, fissure, sloping to "downthrow" side, where the beds are at lower level.

number of rivers it has been estimated that, on an average, 600 tons per annum are thus removed from every square mile of land.

Most of the river-borne waste is carried into the sea, but part of it finds a temporary resting-place in lakes or on the convex sides of river bends (p. 121). A great deal of fine material is deposited, as **alluvium**, in deltas and on areas liable to flooding in river valleys.

(2) **Glaciers** and **ice-sheets**, as already noted (p. 121), drag along loose materials between their under surfaces and the land over which they creep. A glacier also carries

along, on its upper side, fragments of various size which have been detached by frost, etc., from the sides of its valley, and make up long lines of rubbish known as **moraines** (Fig. 46), which are dumped in a great heap at its lower end, where the ice melts.

(3) **The Sea** is another important agent of transport, distributing the waste of land by means of its currents, while tidal action continually shifts and sorts the loose materials near the shore.

Marine deposits are for the most part either mechanical or organic in nature (Fig. 49). **Mechanical deposits,** made

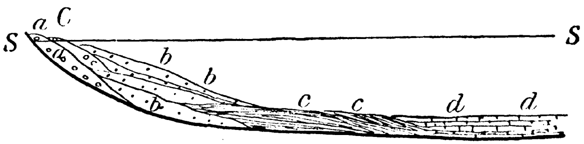


FIG. 49. MARINE DEPOSITS IN VERTICAL SECTION
SS, sea-level ; *c*, coast ; *a*, pebbles ; *b*, sand ; *c*, mud ; *d*, calcareous deposits. Vertical scale much exaggerated.

up of the solid waste of the land, accumulate in the tidal zone and also cover the sea floor in shallow water for an average distance of about 150 miles from the coast. Next the land come pebbles and shingle, which grade into sand, and this again into mud.

Organic deposits of calcareous nature are also to be found, where the water is clear, in the shallower parts of the sea, and these consist of such things as shells and corals, the latter building up the solid masses known as coral reefs. In deeper water, up to about 2,500 fathoms, are to be found very extensive deposits of **calcareous ooze,** a sort of sticky mud, much of which consists almost entirely of the shells of minute protozoa (foraminifera) and may be regarded as chalk in the making. In still deeper water **siliceous oozes** cover large tracts of the sea floor, and these consist of the flinty skeletons of microscopic plants (diatoms), or minute protozoa (radiolaria).

(4) **Wind,** particularly in desert regions, carries sand and other loose materials from place to place, and deposits them in sand dunes, such as are seen on many parts of the British, French, and Belgian coasts. Wind-borne deposits are often finely stratified.

Movements of the Earth's Crust.—That the crust of the earth is in an unstable condition is proved by the frequent occurrence of earthquakes, and smaller vibrations known as earth tremors are everywhere to be detected by suitable apparatus. But of greater interest and importance than these, for our present purpose, are the slow upward and downward movements, **movements of upheaval** and **subsidence,** that have been going on continually from the first formation of the crust.

A proof of upheaval is afforded by **raised beaches,** evidently originally formed by marine action, but now well above the sea. Examples are found in Norway at heights ranging from 50 to 600 feet, and such beaches also occur at lower levels in Scotland, North England, and South Devon. Local subsidence is vouched for by the **submerged forests** exposed at low tide on various coasts. They are to be seen, for example, in Cardigan Bay and off the Wirral peninsula in Cheshire. It may also be added that **fiords**, narrow winding arms of the sea, characteristic of West Scotland, West Ireland, Norway, and Chile, cannot be due to marine action, but are regarded as 'drowned valleys,' originally excavated by rivers but now invaded by the sea as a result of downward movement of the land.

Aqueous rocks are, for the most part, consolidated marine deposits which have been raised above sea level by movements of upheaval, and there can be no doubt that every part of the British Isles and most other parts of the land have been submerged, not once only, but many times, beneath the sea, by movements of subsidence, which have alternated with movements in the contrary direction. The distribution of land and water has thus undergone continual change. We know, for example,

that at a comparatively recent date, geologically speaking, our islands were connected with one another and with the adjacent continent.

THE GEOLOGICAL RECORD.—By piecing together observations made at many different places it has been found possible to arrange the stratified rocks according to their age, and the complete series thus determined is commonly known as the **geological record.** The most important test of relative age is **superposition.** In other words, if in a cliff or quarry we find a series of strata lying on top of one another those below must be older than the ones above

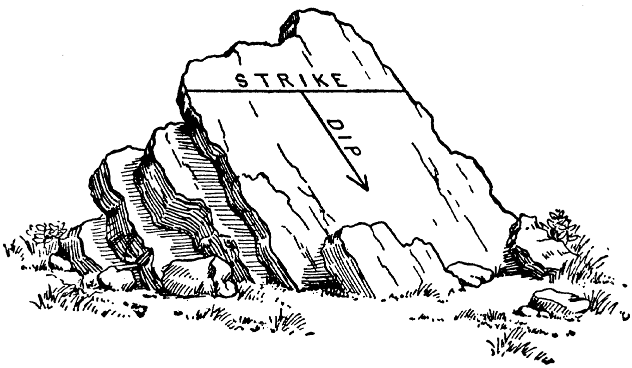


FIG. 50.—STRATA SHOWING DIP AND STRIKE

them. The various deposits on the sea floor are arranged in horizontal or slightly inclined layers, and when converted into land by movements of upheaval they sometimes preserve this arrangement, in which case their relative age is easily seen. More frequently, however, upheaval has tilted these deposits to a greater or less extent, so that they have become **inclined** or even **vertical** strata. Crust movements have also resulted in more or less complex **folding,** and sometimes, especially in mountain regions, strata have been **inverted** or turned over, so that the proper order is reversed. The general trend or direction

of an inclined stratum is called the **strike**, and the maximum slope the **dip** (Fig. 50), the angle of this being calculated with reference to the horizontal plane. Strike and dip are mutually at right angles.

Fossils (Fig. 51).—The deposits which become converted into stratified rocks usually contain the remains of plants and animals, and the organically formed rocks are mainly composed of these. Such remains are known as **fossils**, and this term also includes material proofs of the former existence of organisms, e.g. impressions left by seaweeds or jelly-fish on fine-grained mud, and even the footprints of animals.

The study of fossils enables us to reconstruct, in broad outline, the past history of plants and animals for an

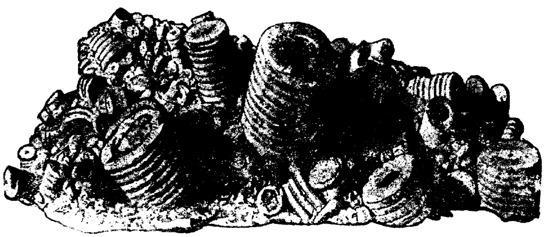


FIG. 51.—FOSSILS
Stems of Sea Lilies (*Crinoids*) in limestone.

immense period of time, embracing many millions of years. It demonstrates that there has been a gradual development or **evolution** from lower to higher forms. Seedless plants, for example, existed before seed plants, and among back-boned animals fishes are a much more ancient group than birds or mammals. We also find that large numbers of species, genera, and families, as well as some larger groups, have entirely died out or become **extinct**.

Fossils are of practical value as tests of age, every set of strata containing characteristic species which are found nowhere else. It is often possible therefore to determine the geological date of rocks exposed in a small quarry or

cutting even when the test of superposition cannot be applied.

Rocks of almost all ages are represented in Britain, and some of the most important facts are summarized in the following table. The geological map which serves as a frontispiece to this book is one of the **solid geology** of the British Isles, all the soils and superficial deposits, except alluvium, being supposed removed. The colours employed are arbitrary, and do not correspond to what is seen in nature. It may be added that the matter is one of great importance in agriculture, for soils are apt to vary in character according to the rocks on which they rest. This, of course, is more particularly true of sedentary or local soils. The solid geology of a district has a great influence on its drainage, and also determines the nature of the local building stone and road metal.

TABLE OF STRATA
(Oldest at the bottom)

GROUPS	SYSTEMS	
Tertiary (Kainozoic)	Quaternary	Recent.
		Pleistocene.
	Pliocene (Crag).	
	(Miocene).[1]	
	Oligocene.	
	Eocene.	
Secondary (Mesozoic)	Cretaceous	Chalk.
		Wealden.
	Jurassic	Oolite.
		Lias.
	Trias.	
Primary (Palaeozoic)	Permian.	
	Carboniferous	Coal Measures.
		Millstone Grit.
		Carboniferous Limestone.
	Devonian (and Old Red Sandstone).	
	Silurian.	
	Ordovician.	
	Cambrian.	
Precambrian (Archaean)		

[1] Not represented in Britain.

CHAPTER VIII

SOILS

SOILS and subsoils are among the youngest rocks of the geological record, which, together with other superficial deposits, are collectively known as 'recent.' (*See* table, p. 130). Ancient soils belonging to earlier geological periods are also known, such as the 'under clays' on which some seams of coal rest, but most of them have long since been destroyed and removed by the action of disintegrating and transporting agents. In any case we are only concerned with those which belong to the recent series.

ORIGIN OF SOILS.—Since soils have come into existence by the disintegration of other rocks they must obviously vary in character according to the nature of the particular rocks from which they have been derived. The first formed crust of the earth was of igneous nature (p. 117), and as this furnished the material for all the rocks with which we are acquainted, it is obvious that soils have been derived from the same source. To this, however, there are important exceptions, for the nitrogen and carbon in certain mineral compounds (e.g. nitrates and carbonates) have been extracted from the air, and the same is true for the combined water that is found in many mineral compounds, which are then said to be *hydrated.* Clay, for instance, is largely composed of hydrated silicate of alumina.

That igneous rocks can crumble down in time owing to the action of weathering agents, thus producing soil materials, is strikingly seen in the case of granite. This varies considerably in composition, but always contains

silica in the form of **quartz**, and complex silicates, chiefly **felspar** and **mica**, but also including smaller amounts of other minerals. There may be a still smaller quantity of **apatite**. Sand, clay, carbonate of lime, potash compounds, and phosphates are all typical mineral constituents of soils, and these are among the products resulting from the breaking down of granite. **Sand** is derived from the quartz and partly from the silicates, the latter also yielding **clay**, together with carbonates which are carried off in solution. A variable amount of a soluble **carbonate of lime** is one of these last compounds, but it is produced much more abundantly by the weathering of certain other igneous rocks, e.g. basalt. Orthoclase, the chief felspar in granite, is rich in **potash**, and apatite is a **phosphate**.

SOIL AND SUBSOIL.—The **soil**, or earth, is the surface layer of comparatively loose material that has been brought into existence by the action of agencies already described (p. 119), and which also contains a varying amount of **humus**, a dark substance of organic origin and exceedingly complex chemical composition. Surface deposits, such as blown sand or china clay, which do not contain humus, cannot be regarded as soils, though they may supply the mineral framework of future soils. Humus is essential to the growth of crops, and also to the life of innumerable underground organisms. These include the soil bacteria and protozoa, of which a brief account has been given elsewhere (p. 106). They are of extreme agricultural importance, and much remains to be learnt about them. They are almost inconceivably numerous: "The very incomplete census taken so far shows that the numbers of micro-organisms living in a single salt-spoon full of soil must be reckoned in millions." (E. J. Russell, *Fertility of the Soil*, p. 9.)

The soil is also inhabited by larger animals, such as moles, field-voles and earthworms; and it harbours the larvæ and pupæ of many insect pests.

The name **subsoil** is applied to the material underlying the soil, and into which this often gradually merges without

any sharp line of demarcation. The ordinary acts of tillage affect the soil only, but drains are laid in the subsoil, which is also cut into when the subsoil plough is used.

The subsoil in its turn may grade into firm rock below, as in the case of many typical sedentary soils (Fig. 52).

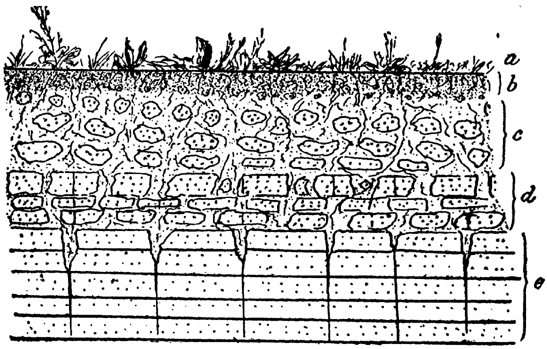


FIG. 52. FORMATION OF SEDENTARY SOIL

a, Plant growth; *b*, soil; *c*, subsoil; *d*, rock, breaking up; *e*, sandstone rock, stratification indicated by horizontal and jointing by vertical lines. Note plant-roots stretching down into *e*.

Subsoil is penetrated by the roots of some plants, and the decay of these furnishes a certain amount of humus, though not so much as in soil, while it is relatively poor in microscopic organisms and plant food. It is richer than soil, however, in very fine particles of mineral matter, as these are continually being washed down into it by the percolation of rain water.

South of the Thames a map of the solid geology affords a clue to the general character of the sedentary soils present, for these and their subsoils have been derived from the underlying rocks there represented. But north of the Thames large areas are covered by ice-borne deposits (boulder clay and drift) which may be regarded as **transported subsoils.** The upper part of these has crumbled down into soils, the nature of which is not indicated by the map of the solid geology. In such cases maps of the **surface geology** are very useful, and these are published

by the Geological Survey for some parts of the country. But even these are really **subsoil maps**, such as those published by the Soil Survey of the United States. The soils themselves show such a large amount of variation even in small areas that detailed maps of their distribution, for even a single country, would involve immense labour and much expense in their preparation. A valuable preliminary attempt in this direction has been made by Hall Russell in their *Report on the Agriculture and Soils of Kent, Surrey, and Sussex.*

Soils to which the name 'transported' is properly applied commonly differ from the subsoils on which they rest, but from which they have not been derived. Clay overlying sand or limestone is not uncommon, affording an exception to the general rule that it is undesirable to bring crude subsoil to the surface. For in such cases a heavy clay may be improved by admixture with a reasonable proportion of subsoil.

STRUCTURE OF THE SOIL.—The soil has already been briefly described as a mixture of fragments of different size and kind, traversed by a system of spaces in which air and water circulate (p. 10). Much light has been thrown on its structure by the method of **mechanical analysis,** but the details are too complicated for full treatment here, and those specially interested are referred to Hall's book *The Soil.* The calcareous matter and part of the humus are removed by treatment with hydrochloric acid, after which the sample is washed and air-dried. Stones of any size are picked out by hand and the coarser materials are sorted out by sifting through wire sieves with meshes of different dimensions. The smaller particles are then divided according to their size by mixing them with water and allowing them to settle, the operation being repeated a number of times. The finest particles are collected by evaporating all the water that remains turbid after being allowed to stand for twenty-four hours. This method of **sedimentation** for sorting out the fine material can be replaced by one of more elaborate nature,

where particles of different size are separated by the use of jets of water varying in velocity.

The components of the soil are named according to an arbitrary scale of size, that employed in this country being given in the following table (from Hall). There is of course no such sharp division in nature, but a gradual passage from one end of the series to the other.

DIAMETER IN MILLIMETRES

		Maximum.	Minimum.	
1.	Stones and Gravel	—	3	Separated by sifting.
2.	Fine Gravel	3	1	
3.	Coarse Sand	1	0·2	
4.	Fine Sand	0·2	0·04	Separated by subsidence.
5.	Silt	0·04	0·01	
6.	Fine Silt	0·01	0·002	
7.	Clay	0·002	—	

That part of the humus not dissolved out by acid is contained in the fine silt and clay, and this is removed by the application of heat.

The stones and gravel vary greatly in nature and chemical composition according to their origin: the sand, silt, and coarser part of the fine silt, chiefly consist of silica: while the finest part of the soil is chiefly made up of hydrated silicates of alumina, potash, soda, and ammonia. This finest part (clay and the finer part of the fine silt) is chemically active as compared with the coarser material, and contains the plant food. It also—and the same is true for humus—possesses characters which are distinctive of bodies known as **colloids** (Gr. *kolla*, glue; *eidos*, resemblance). These absorb water and swell up into a jelly-like condition (gels), or may even become imperfect solutions (sols), but in this case are not able to diffuse through moist plant or animal membranes. Familiar examples are afforded by starch, gum, gelatine, and albumin.

When the sticky colloidal part of the soil is exposed to the action of the weather it becomes more porous and less tenacious. This is because its fine particles temporarily run together into larger aggregates: in technical language,

it undergoes **flocculation.** This is greatly promoted by very small quantities of various salts in solution, one being calcium bicarbonate which is constantly being formed from the calcareous part of the soil. A clay soil is therefore improved in texture by liming or chalking. On the other hand, if worked when wet it once more becomes sticky and intractable, for the fine particles are separated again. In other words, it is **deflocculated.**

The structural relations between the different parts of the soil have been popularly expressed by defining it as: 'a porous mass made up of a hard framework plastered over with a jelly containing chemically active substances, plant foods, and unstable organic compounds rich in stores of easily liberated energy, while the pores contain air and a considerable amount of water.' (E. J. Russell, *The Fertility of the Soil,* p. 10.)

Water and Air of the Soil.—A certain amount of water in the soil is essential for the life and growth of crops, but their roots also require air for breathing, so that soil completely saturated with moisture is useless for agricultural purposes. The so-called 'free' water is that which is removed by natural or artificial drainage, but even when this has been effected a large amount of water is left behind in the form of stretched films coating the particles of soil, the films of adjacent particles being continuous. This film system furnishes the water which, together with mineral substances dissolved in it, is absorbed by root hairs as plant food. The films vary in thickness according to the dryness or dampness of the soil, and there is a constant creep as it were of water from particle to particle, the direction being from damp soil to dry. If, therefore, a root hair absorbs part of the film covering a particular particle, this will be replaced by some of the water covering adjacent particles; these in their turn will draw on the films of their neighbours, and so on indefinitely. There is thus a continual movement of plant food towards root hairs, so that the root is not restricted to the supply in its immediate neighbourhood.

Free water flows downwards under the influence of gravity, and film water moves in any direction from wet soil to dry, but besides this there is an upward movement of water by means of what is known as **capillary attraction.** If an exceedingly narrow or capillary glass tube is dipped into water, this will rise in it to a height depending on the internal breadth of the tube. The narrower the tube the greater the height reached by the water. The cracks and crevices that make up a continuous system of irregular spaces in ordinary soils act in the same way. This is familiarly illustrated by the common piactice of watering pot plants from below, and in similar fashion a soil is able to draw upon the water that saturates the ground below the water table.

Temperature of the Soil.—Seeds are unable to germinate or crops to grow except within certain limits of temperature which vary according to the kind of plant. Germination or growth begins at a **minimum** temperature, becomes more vigorous as this is raised to an **optimum**, and gradually slows down until a **maximum** is reached. This is illustrated by the two following tables for some common cultivated plants, expressed in Fahrenheit degrees.

GERMINATION TEMPERATURES

	Minimum.	Optimum.	Maximum.
Wheat	32 to 41	77 to 88	88 to 110
Barley	40	77 to 88	100 to 110
Oats	32 to 41	77 to 88	88 to 100
Pea	38 to 41	77 to 88	88 to 100
Scarlet Runner	49	91	115
Maize	49	91	115
Cucumber, Melon, etc. ..	60 to 65	88 to 99	110 to 120

GROWTH TEMPERATURES

	Minimum.	Optimum.	Maximum.
Mustard	32	81	99
Barley	41	83·6	99·8
Wheat	41	83·6	108·5
Maize	49	92·6	115
Kidney Bean	49	92·6	115
Melon	65	91·4	111

The greater part of the heat received by the soil is by direct radiation from the sun, and a southern aspect is most favourable for this purpose in the northern hemisphere. Part of this heat is radiated into the air and lost, but dark soils have an advantage both ways, for they absorb more and lose less. It therefore follows that a dressing of soot, provided it is only just enough to impart a dark colour, distinctly warms the soil. The soil also receives heat when warm rains fall upon it, and a good deal is generated by the decay of organic matter.

The soil loses heat not only by radiation but also by conduction downwards, as well as upwards into the air. There is further a very considerable loss as the result of evaporation of water from the surface. Mulching and hoeing, by checking evaporation, not only conserve moisture but help to keep the soil from parting with heat.

CLASSIFICATION OF SOILS.—Many different kinds of soil are known, but it is extremely difficult to classify them with any approach to accuracy, for they pass into one another by insensible gradations, so that in many cases the particular name that should be applied is a matter of opinion. It is easy, however, to distinguish between a few leading types, as recognized in farm practice, and the differences between these are primarily due to texture, and this depends on the size and character of the component particles. In **sand** the coarser particles predominate, and in **clay** the finer ones, while a **loam** is intermediate between the two. It is particularly important to notice that the word 'clay' is applied to four different things:—(1) to clay soils; (2) in the mechanical analysis of soils, to particles less than ·002 mm. in diameter, making up what may be called 'raw clay' for the sake of avoiding confusion; (3) in mineralogy, to hydrated silicate of alumina, more or less impure, forming a soft plastic substance produced by the disintegration of felspars and similar minerals; (4) to that part of a clay soil conferring its special characters, and which may be termed 'argillaceous material.'

This last is made up for the most part of raw clay, plus

part of the finest silt, and a considerable portion of both these is hydrated silicate of alumina with various impurities. But this is not all, for argillaceous material is the colloid part of soil, embracing part of the humus, and the mineral matters that serve as plant food. As a matter of fact our knowledge of the subject is still very incomplete, and indeed the same may be said about most of the facts and principles which underlie the practice of agriculture.

Carbonate of lime is an essential constituent of every fertile soil, and 5 per cent or more of it is present in **calcareous soils**, which vary in texture according to the proportion of sand present, but behave like clay soils with regard to wet and dry weather. Clay soils containing from 5 to 20 per cent of carbonate of lime are often known as **marls**.

Humus also makes up part of all soils, and is present in large amount in the **peaty soils** of fens and moorlands.

FERTILITY OF THE SOIL.—Fertile soils are those in which crop plants, including the vegetation of grass land, can not only live but flourish, so that they can be grown with more or less profit. But as the requirements of the different crops are not precisely the same, a particular soil may be fertile as regards some of them, but infertile in respect of others. It therefore follows that a farmer cannot expect success unless he cultivates the crops for which his land is suitable, or can be made so by appropriate treatment, always provided that the cost of such treatment is not prohibitive. There are six chief things that require consideration (*see* Russell, *The Fertility of the Soil*, p. 27)—water, air, temperature, plant food, root range, and absence of harmful factors.

Water must be present in sufficient amount, but excess is injurious, as this prevents the access of air to the roots. The supply of water ultimately depends upon rainfall, which is beyond our control, but has much to do with variations of farm practice in different districts. Once received, water may drain away too quickly, or too slowly, as determined by height above sea level, and the nature of the soil,

subsoil, and underlying rocks. It is often necessary to conserve the moisture in sandy soil by checking evaporation from the surface (p. 137), while its retentiveness may be increased by addition of bulky manures or by raising and ploughing in some rapidly growing crop, such as mustard. Clay soils, on the other hand, are apt to be too retentive, and this fault must be corrected by addition of chalk or lime, breaking up hard layers or 'pans' that hold up the water, or the adoption of an efficient system of drainage.

Drainage is a highly technical matter, but a few points may be mentioned here. Ditches should be cleared out, and in some cases it is necessary to deepen them, so as to promote the flow of water. Pipe drains are then laid in the ground at a depth of 3½ to 4½ feet. A distinction is drawn between main and branch drains. The former are commonly 4 inches in diameter, and of course occupy the lowest levels, sloping down to suitable outlets, and protected by gratings where they open, to prevent the entry of rats. Branch drains vary from 2 to 3 inches in diameter, and are placed parallel with one another, following the slope of the ground, at from 18 to 36 feet apart. In stiff soil they should be closer together than in lighter soil. The junction with a main drain must be slanting, and point in the direction of flow.

Air must circulate freely in the soil if the roots of crops are to be kept healthy, and it is also necessary to the bacteria that prepare plant food (p. 106). Drainage and other devices for removing superfluous water of necessity provide for the access of air, and it must be remembered that the extent to which the water table should be lowered depends on the length of the roots of the crops to be cultivated. Grasses, for example, are shallow-rooted, while lucerne is very deep-rooted.

The **temperature** of a dry sandy soil is more quickly raised by the sun's heat than that of a damp clay soil, the reason being that a given bulk of earth requires only one-fifth as much heat as the same bulk of water to warm it to the same extent. Much heat is lost when water evaporates at the

surface, and the methods for checking this so as to conserve moisture (p. 137) also prevent loss of heat. It is also possible to increase the amount of heat absorbed, as by soot dressings on light-coloured soils (p. 137), while by ridging-up east and west the southern slope of each ridge will be at an advantage. Nor must it be forgotten that decay of organic matter in the soil is one source of heat, so that the addition of dung and similar bulky manures will warm the ground.

Plant Food must be present in the soil in sufficient amount and in a soluble state if a soil is to be fertile, and a brief account has already been given of the requirements of crops in this direction (p. 11). Deficiencies are supplied by the application of suitable manures, and the practical treatment of the most important crops is fully explained in the volume on *Crops and Tillage* in this series. Something is said about the principles of manuring in the next chapter.

Root Range.—A plant cannot attain to the fullest development of which it is capable unless its roots are able to branch freely, so that they may absorb as much plant food as possible. The extensive nature of the root system has been very clearly demonstrated by calculations made in certain cases. It was found, for instance, for a particular wheat plant, that if all its roots had been cut off and placed end to end they would have stretched 568 yards. For winter wheat the maximum development of the root system is attained about the end of April, at which time its dry weight is about half that of the entire plant. Such facts clearly prove the necessity for thorough tillage, while by efficient drainage the water table must be lowered so as to bring it well under the root zone of the crop which is being cultivated. Care must also be taken to remove weeds, as their roots interfere with those of the crop, and even appear to exert an injurious action upon them, as in the well-known case of grass and fruit-trees.

Harmful factors are often present, and these require elimination. Excess of water has already been considered

(p. 139), but what is called ' sourness ' is of a more positive character, though its precise nature is not yet understood. It can, however, be corrected by liming, drainage, and thorough tillage. Many other problems of the kind present themselves when the reclamation of land is attempted, but their consideration is beyond the scope of this book. They are suggestively treated, so far as this country is concerned, in Hall's *Agriculture after the War.*

CHAPTER IX

PRINCIPLES OF MANURING

ALTHOUGH most soils will bear crops without any kind of manurial treatment, this is practically always necessary for securing a remunerative yield, and as agriculture becomes more and more intensive there will be increasing necessity for replenishing and augmenting the store of plant food. Subjected to chemical analysis a given soil may appear to contain plenty of this, but unless it be in an available form it cannot be taken up by crops. An ordinary analysis of the kind is often distinctly misleading for this reason, but attempts are commonly made to calculate the available food. The availability of phosphoric acid and potash is roughly determined by treating a sample of soil with 1 per cent citric acid, when the amount of these compounds dissolved out more or less corresponds to that which can be absorbed by roots from the soil in question. In this way it is possible to find out if a soil is urgently in need of phosphoric or potassic manure.

Field experiments are, at present, the best guide to manurial treatment, and they give information as to the paucity or otherwise of all kinds of plant food. But they have to be very carefully planned, and unless the nature of the soil and all other local conditions are taken into consideration they may be worse than useless. Even within the limits of a single field of moderate size there are often considerable variations in the nature of the soil, especially in cases where transported deposits adjoin those of sedentary nature. The results of accurate soil surveys, plotted on large scale maps of not less than six inches to

the mile, would obviate many mistakes in applying to farm practice the results of field experiments.

Limiting Factors.—The chief requirements of crops were summarized in the last chapter, and all of these impose limits to the possible yield. It may, for example, be impossible to increase this beyond a certain amount on account of the dryness of the soil, and in this case water becomes a limiting factor. Again, the physical and chemical characters of a soil may be ideal, except that the water table is too near the surface for full development of the roots, and the yield is thereby kept down. Here the limiting factor is root range.

The rational application of manures primarily depends upon the **Law of Minimum**, which is simply another way of expressing the nature of limiting factors, more particularly those connected with plant food. Somerville (*Agriculture*, p. 106) states it very clearly as follows : '. . . the yield of a crop depends upon the available supply of that essential element of plant food that is present in least amount. Put into other words, the law implies that no superabundance of plant food generally can compensate for deficiency in an essential element. In popular language, the law may be illustrated by a chain, whose strength is necessarily determined by the weakest link.'

The essential elements in question (cp. p. 2) are eleven in number, i.e. carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, sodium, magnesium, calcium, and iron. Plants obtain the carbon and part of the oxygen they require from the carbon dioxide of the air ; while the water in the soil supplies the necessary hydrogen and the rest of the oxygen, besides acting as a solvent for other kinds of plant food. Water is in fact to be regarded as the most important manure. Iron is only wanted in very small amount, and is available in all soils and it is very rarely necessary to take sodium, magnesium or sulphur into consideration. It therefore follows that manuring essentially consists in the use of compounds containing calcium, nitrogen, phosphorus and potassium.

LOSSES AND GAINS OF THE SOIL.—When left uncultivated a soil does not usually lose in fertility, and may even improve in character, up to a certain limit. This is one advantage to be derived from a **bare fallow**, or period during which no crop is grown, and the soil bacteria are able to increase the supply of nitrates (p. 106). But as these are easily washed out of the soil the advantage is lost in a wet climate. The introduction of fallow or catch crops was devised as a means of combating this loss.

The soils of a farm, however, will steadily decline in fertility without manurial treatment until a stage is reached where the yield remains practically steady, though too small to be profitable. The decline is of course due to the losses in plant food more or less exceeding the gains. There are three chief sources of **loss**:—(1) Removal of crops. (2) Liberation of nitrogen in the free form as a result of bacterial action (p. 107). (3) The washing-out of plant food into the drainage water. The natural sources of **gain** in unmanured soils are: (1) The slow conversion of unavailable plant food into the available form by weathering, underground water, and the solvent action of plant roots. (2) Addition of very small quantities of ammonia and nitrates from rain, or by direct absorption from the air. (3) Formation of nitrates by nitrifying and nitrogen-fixing bacteria (p. 106). (4) The solid and liquid excreta of grazing stock. A few facts regarding some of these losses and gains will make the matter clearer.

LOSSES.—(1) **Removal of crops.**—The following examples are given by Somerville (*Agriculture*, p. 102): 'A crop of cereals, grain and straw, will, on the average, remove from an acre of land about 50 lb. of nitrogen, and 20 lb. of phosphoric acid; while a crop of turnips, bulbs and leaves, will similarly remove about twice as much nitrogen and 50 per cent more phosphoric acid; whereas mangolds take from the land about fifty per cent more nitrogen, and an even larger proportion of phosphoric acid than a crop of turnips. As regards potash, the variations are also very wide, turnips, for instance, removing about 150 lb.

per acre, as contrasted with less than 30 lb. in the case of wheat.'

(2) **Liberation of free nitrogen.**—This appears to be of little importance in unmanured soil.

(3) **Loss by Drainage.**—Various soluble substances are washed out of the soil, especially if this is not covered by vegetation. Of these the most important are **nitrates**, and for fallow ground at Rothamsted the average loss per annum is calculated as 188 lb. per acre. In the case of some uncropped and uncultivated ground in France the loss was 186·7 lb. per acre, during a period in which the total rainfall was 28·8 in.

GAINS.—(1) **Weathering, etc.**—The production of available plant food in this way takes place for the most part so slowly that its influence on agriculture need hardly be taken into consideration.

(2) **Rain, etc.**—Calculations made at Rothamsted give about 5 lb. of nitrogen compounds per acre as the average amount gained from a year's rainfall. On the western side of Britain the amount would be greater in proportion to the larger rainfall.

(3). **Nitrates produced by bacterial action.**—For twenty-six successive years the drainage waters from an uncultivated and regularly weeded soil mass at Rothamsted ($\frac{1}{1000}$ ac. × 20 in. in depth) were systematically analyzed. The average annual loss in nitrates was shown to be 36·3 lb., and subtracting from this the 5 lb. due to rainfall the remainder—31·3 lb.—must have been formed by bacterial action on the humus. A great deal more is generated in this way in soil covered by vegetation. (Cp. loss by drainage as given above.)

(4). **Excreta of Stock.** The greater part of the nitrogen, phosphoric acid, and potash, in the food of farm animals is not used within their bodies, but passes out again to the exterior in their solid and liquid excreta. 'Fattening animals and working animals excrete 95 per cent of the nitrogen they eat; young stock, milking cows, and pigs, only about 70 to 80 per cent.' (T. B. Wood,

Crop Production, p. 152.) The following table (from A. D. Hall) gives the percentage composition of excreta as regards nitrogen, phosphoric acid, and potash.

Animal.	*Excreta.*	*Water.*	*Nitrogen.*	*Phosphoric Acid.*	*Potash.*
Horse	Solid	75·0	0·56	0·35	0·1
	Liquid	90·0	1·52	trace	0·92
Cow	Solid	86·0	0·41	0·12	0·04
	Liquid	91·5	1·05	trace	1·36
Sheep	Solid	57·6	0·72	0·44	—
	Liquid	86·5	1·31	0·01	—
Pig	Solid	76·0	0·48	0·58	0·36
	Liquid	97·6	0·50	0·14	0·70

Manurial values for the different kinds of feeding-stuff have been carefully calculated, and it is clear that such of these as are purchased add more or less to the plant food in the soil, after having discharged their primary duty.

UTILIZATION OF WASTE.—That crop residues and the excreta of farm stock should be returned to the soil so far as possible is a principle of manuring that has always been recognized, and is of primary importance. Until the beginning of last century farmers relied almost entirely on such 'natural' fertilizers as farm-yard manure or dung, together with marl, some form of lime, and similar mineral substances.

Crop residues are of obvious importance, including as they do an immense quantity of plant roots, which maintain and increase the amount of humus in the soil. The accumulation of combined nitrogen owing to the nodule bacteria of leguminous roots (p. 107) should be noted in this connection. It may also be possible to return to the soil parts of a crop that are not harvested, and these may be rich in compounds of manurial value: 'Thus the tops of a crop of turnips contain a large part, nearly half, of the nitrogen taken from the soil by the crop, as well as a considerable amount of phosphate and potash. When the tops of an average crop of turnips are left on the soil they restore to it as much nitrogen as is contained in a dressing of 2 cwt. of sulphate of ammonia, as well as the equivalent in potash of about 3 cwt. of kainit, and the

equivalent in phosphate of nearly 1 cwt. of 26-per-cent soluble superphosphate. Land on which the tops are left, therefore, is always in much better condition for the succeeding crop than that from which they are removed.' (J. Hendrick, *Standard Cycl. of Modern Agr.*, viii, p. 186.)

Farm-yard Manure or **Dung** consists of the solid and liquid excreta of stock, together with litter, most commonly straw. It is a complete or general manure, as might be expected from its origin, returning to the soil plant food of all kinds, but there are great variations in its composition and consequently in its value as a fertilizer. The excreta of different kinds of animal are by no means alike either in physical or chemical constitution (p. 146), and even those of the same sort of farm stock vary according to age, nature of the food, and requirements of nutrition. Fattening bullocks, for example, give richer manure than young growing animals or milk cows. The litter employed may also vary greatly in character, while the methods of making and storing are by no means uniform, sometimes tending to conservation of fertilizing ingredients, but more frequently leading to deterioration in quality.

In a ton of farm-yard manure there are, on the average, from ten to fifteen lb. of nitrogen, twelve of potash, and five to eight of phosphoric acid. The amount of potash is ample, but it is usually found necessary to add to the nitrogen and phosphoric acid by the use of suitable artificials, in addition to the dung. The chemical composition of farm-yard manure does not indicate its immediate utility so far as nitrogen is concerned, for the compounds of this element present in the litter only are very gradually converted into an available form, so that their influence is spread over a series of years. It is quite otherwise with the nitrogenous waste products in the urine, for these become available very quickly, and a large proportion of them is apt to be lost entirely if the methods of making and storage are inadequate.

The heat generated in a mass of manure is one indication

of active chemical changes due to bacterial action, and which may conveniently be called **fermentation.** As a result of this the nitrogenous compounds of the urine are exposed to the action of two groups of bacteria, ammonifying and denitrifying, as has been briefly explained elsewhere (p. 106). Denitrifying bacteria cause these compounds to break up with liberation of gaseous nitrogen, an obvious loss to the farmer. Their action can only go on when free oxygen is absent, as in manure completely saturated with moisture, so that it can be arrested by thorough ventilation. Ammonifying bacteria, which lead to the production of ammonium carbonate, require a supply of free oxygen, and are therefore active in well aerated manure. But if this is allowed to get too dry the carbonate breaks up with formation of free ammonia, which is given off into the air, resulting in loss of nitrogen. Enough water must be present to keep the ammonium carbonate in solution until it can be exposed to the action of nitrifying bacteria in the soil. The dark liquid that oozes from a manure heap is rich in this substance, and requires most careful conservation. It is too often allowed to drain away as it pleases, instead of being collected in a tank from which it can be pumped back on to the heap.

It is important to bear in mind that farm-yard manure is of great value for improvement of the physical characters of the soil, and thus has an advantage over concentrated artificials. A distinction is drawn between fresh or 'long' dung, and that which is well rotted or 'short.' Clay soils are much benefited by application of long dung, as this promotes drainage and aeration. Light sandy soils, on the other hand, are rendered firmer and more retentive by dressings of short dung, but these should be given at a time when crops are ready to use their abundant supply of available plant food, much of which would otherwise be drained away and lost.

Artificial Farm-yard Manure (Straw Manure).—This is prepared by treating straw with ammonium sulphate and chalk. Encouraging expermiental results have been

obtained, but the process has not yet been carried out on a commercial scale.

Liming, Chalking, and Marling.—The object of all these operations is to add calcium carbonate to the soil, this being especially required by all leguminous and cruciferous crops. Calcium is an essential element in plant food, but this is not the primary reason for applying lime, as it is present in one form or another in nearly all soils to a sufficient extent to meet this particular demand. But the decay of humus results in the production of acid compounds, lumped together under the somewhat vague name of **humic acid,** and nitrifying bacteria (p. 106) cannot do their work unless this is neutralized, as it is by bicarbonate of lime, which is produced as a sequel to liming, chalking, or marling. This kind of treatment also corrects 'sourness,' whatever that may be (p. 141); and flocculates clay (p. 134), thus facilitating the working of heavy soils and at the same time promoting their drainage and aeration. **Club-root** or **finger-and-toe** of turnips and other cruciferous crops, due to a microscopic parasite (*Plasmodiophora brassicae*), is associated with deficiency in lime, and so are certain **weeds**, such as common sorrel (*Rumex acetosa*), sheep's sorrel (*R. acetosella*), spurrey (*Spergula arvensis*), corn marigold (*Chrysanthemum segetum*), and bracken fern (*Pteris aquilina*). Dressings of lime abolish such pests, and also keep down mosses and certain weed grasses, including bents (species of *Agrostis*), wavy hair-grass (*Aira flexuosa*), and Yorkshire fog (*Holcus lanatus*). It may be added that lime neutralizes the acidity of certain artificial manures, such as superphosphate, and liberates potash from some of the soil silicates, thus making it available as plant food.

From what has been said it will be realized that to be fertile a soil must contain a certain proportion of calcium carbonate, and it is easy to find out whether there is a deficiency. This is indicated by the presence of the weeds mentioned above, but in any case a simple chemical test should be applied. A small quantity of soil is well mixed

with water and a little strong hydrochloric acid added. Brisk effervescence, indicating liberation of carbon dioxide, proves the presence of sufficient calcium carbonate; faint crackling only to be detected by hearing shows scarcity of this compound; and a negative result means that too little is present, if any. If a pinch of damp soil when placed on a piece of blue litmus paper turns this red, the soil is undoubtedly acid and requires addition of lime.

ARTIFICIAL MANURES.—These are applied to soils deficient in nitrogen, phosphates, or potash, or more than one of these. Plant food is only available when in solution, and therefore artificials act quickly or slowly according to their degree of solubility. It follows that if immediate results are required it is necessary to select the more soluble manures, but if gradual improvement is the end in view it may be preferable to choose those which are less soluble and consequently act more slowly.

Nitrogenous Manures.—Crops take up the nitrogen they require in the form of nitrates, and the formation of these in the soil has already been discussed (p. 106). It may be necessary to supplement the supply by addition of nitrogenous artificials, and among these **nitrate of soda** $NaNo_3$) or Chile saltpetre (p. 12) has been universally employed as a source of immediately available nitrogen. But it is extremely soluble, and unless the soil is full of plant roots at the time of its application is liable to be washed out into the drains and lost, the rate of loss depending on the local rainfall. Like other very soluble manures, however, it soon reaches the feeding zone of deep-rooted crops.

Until comparatively recently the world's yield of wheat so largely depended on the use of nitrate of soda that the rapid depletion of the natural supply of this substance caused serious anxiety. In 1898 Sir William Crookes suggested the possibility of employing electric power for causing the nitrogen of the air to enter into combination. and **nitrate of lime** $(Ca(No_3)_2)$ is now made in this way (p. 12). This is not only a good substitute for nitrate of

soda, but also helps to correct the bad qualities of soils deficient in calcium carbonate.

Other nitrogenous manures act less rapidly than the two just mentioned, for more or less time is taken up by the conversion of their nitrogen into the form of nitrate, and consequently shallow-rooted crops derive more immediate benefit from their application than those which are deep-rooted. **Calcium cyanamide** (nitrolime), like nitrate of lime, is made by causing atmospheric nitrogen to enter into combination, but its composition is different ($CaCN_2$). When added to the soil it yields ammonia, which is then converted into nitrate.

Sulphate of ammonia ($(NH_4)_2SO_4$) is a gasworks product which has a certain advantage over nitrate of soda in places where the rainfall is considerable, for it is less soluble and more readily retained in the soil.

There are also **organic nitrogenous manures** which though slower in their action than sulphate of ammonia decompose with sufficient rapidity to be of use in the year of application. They yield ammonia, which is then nitrified, and also supply a certain amount of phosphate and potash. Among them are included nitrogenous guanos, blood manure, fish manure, and fertilizers compounded of waste oil-seeds. **Peruvian guano** consists of excrement and other refuse from the nesting places of marine birds on the coasts of Chile and Peru, and some of the adjacent islands, especially the Chinchas. Nitrogenous deposits of the kind are only possible in a hot dry climate, and it should be noted that nitrate of soda comes from the same part of the world. In fact, the nitrogen of this compound was probably derived from ancient guanos. The first cargo of Peruvian guano reached Europe in 1840, and the new manure at once became popular, owing to the rapidity of its action as compared with the slow fertilizers then in general use. The large demand led to the almost complete depletion of the high grade deposits by about 1870, but fresh supplies became available in another twenty-five years. Other sources were also discovered, especially

in Patagonia and the Ichaboe Islands off south-west Africa.

Guano occupies an important place in the history of British agriculture, for it greatly facilitated the adoption of other concentrated artificials and also helped to bring home to farmers the importance of agricultural chemistry. For as the highest class product grew scarcer the malpractice of adulteration became more frequent, and this led to the chemist being called in as a species of detective.

Slowly-acting Organic Manures, such as shoddy, ground leather, waste, and ground hoofs and horns, are of little use for general purposes, but find employment in the case of cultivated plants, such as hops and fruit trees, which live longer than the crops that figure in an ordinary rotation.

Phosphatic Manures are required by nearly all soils, and are of particular importance when seeds or grain constitute the most valuable part of the crop, for these contain more phosphorus than roots, stems, or leaves. They are also a limiting factor for turnips and swedes, and have been largely employed for the improvement of poor grass land. Phosphates are retained by the soil, thus differing from nitrates, and if dressings are applied to the root crop their effect will be felt for the whole of an ordinary four-course rotation.

The history of phosphatic manures is particularly interesting, because—in the form of bones—they were the first kind of artificial to be used in this country, and their employment dates back to the eighteenth century in South Yorkshire. It is alleged that their value for agricultural purposes was discovered by a Yorkshire fox-hunter in 1767. In the first instance fresh bones were broken up into half-inch pieces, and in the *Complete Farmer* (1807) it is stated that: '. . . the common way of treating them is to break them with a mill into pieces the size of a marble or nutmeg; they are afterwards laid upon the land in small heaps, at regular distances, and covered with earth; after remaining in this state for some time they are spread on fallows, or grass, or on turnip land.' Fresh bone is a mixed manure, for it consists of an organic basis of nitrogenous character impregnated with salts of lime, mostly insoluble tricalcic

phosphate ($Ca_3(PO_4)_2$). The yellow marrow in the shafts of long bones is largely composed of fat, but this is of no agricultural value, and is extracted by boiling or some other degreasing process before bones come into the market for manurial purposes.

Half-inch bones were replaced after a time by **bone meal, bone flour,** and **bone dust,** which act more quickly. These should contain a minumum of 48 per cent tricalcic phosphate and 3¾ per cent nitrogen, equal to 4½ per cent of ammonia. Many of the bones used for agricultural purposes are not only degreased before being ground, but also steamed for production of gelatine, thus reducing the amount of nitrogen but increasing the percentage of phosphate. The resulting manure, **steamed bone flour**, contains on an average ¾ to 1½ per cent nitrogen, and 60 to 70 per cent phosphate. This is much more finely divided than bone meal, and acts more rapidly in consequence. Some experiments on turnips carried out by Hendrick show very clearly the advantage of fine division (*Standard Cycl. of Modern Agriculture*, ii, pp. 187–8). Four plots were taken and equally dressed with soluble nitrogenous and potassic manures for two successive seasons. One received no phosphatic manure, the others bone manure of different degrees of fineness but containing the same total amount of phosphoric acid. The yield per acre was as follows :—

	1st Season 4 experiments		*2nd Season average of 6 experiments.*	
	tons	cwts.	tons	cwts.
1. No phosphate	5	15¾	9	18
2. Coarse bone meal, 5 cwts. ..	14	0	15	17½
3. Fine bone meal, 5 cwts. ..	16	17¾	17	12½
4. Steamed bone flour, 4 cwts.	18	1	17	10¾

During the second season there was little to choose between fine bone meal and steamed bone flour, but the latter was cheaper and applied in smaller quantity.

It was suggested by Liebig in 1840 that soluble phosphate might be obtained by treating bones with sulphuric acid.

The same idea had occurred independently to Lawes, the founder of the Rothamsted station, who experimented with the spent bone of animal charcoal from sugar refineries. He took out a patent in 1842 for the manufacture in this way of monocalcic phosphate ($CaH_4(PO_4)_2$), popularly known as **superphosphate**. The name of **dissolved bones** is given to steamed bones or bone ash treated by sulphuric acid. It was soon realized that ground mineral phosphates (p. 117) were even better than bone for the end in view, and these are now used in the manufacture of nearly all the superphosphate on the market. This artificial is without rival where a rapidly-acting phosphatic manure is required, but is not suitable for soils poor in carbonate of lime and therefore acid or sour in nature. It should certainly not be used in cases where finger-and-toe (p. 149) has made its appearance. **Crust guanos,** which have lost their nitrogen, are also valuable phosphatic manures.

Iron ores contain more or less phosphorus, and the Thomas-Gilchrist process invented in 1878 had for its object the elimination of this element, which makes steel brittle. Air is blown through a mixture of molten iron and carbonate of lime, thus oxidizing the phosphorus with formation of a complex phosphate which helps to make up the slag that is formed on the surface. When very finely ground this is the **basic slag**, basic cinder, or Thomas phosphate, that competes with superphosphate as a fertilizer. Though slower in action it is better adapted for soils deficient in lime, as it corrects acidity and sourness. It has been largely employed for the improvement of permanent grass land, provided the soil is not too light, and greatly improves the herbage by first encouraging the growth of wild white clover and other leguminous plants, and subsequently that of the more valuable grasses.

Where superphosphate and basic slag are equally suitable the question of cost is of course taken into consideration, and in doubtful cases a mixture of the two can be used with advantage.

Potash Manures promote the formation of carbohydrates,

such as sugar and starch, and are therefore of particular importance for crops harvested on account of their richness in these, e.g. beet and mangel (sugar), and potatoes (starch). Potash also encourages the growth of stems as compared with leaves and seeds. Most soils possess sufficient available potash for average crops, but potassic manures are necessary for securing large yields of plants containing much sugar or starch. Potash is a limiting factor for some sandy, peaty, and calcareous soils, and must be added in such cases even to obtain small yields.

The chief source of potash manure at the present time is the very large deposit of Stassfurt salts (p. 116), which has been increasingly exploited from about 1859. Before its discovery wood-ashes and burnt seaweed were the only known manures of the kind, and are still of value. Though by far the most important, the Stassfurt salts are not the only known mineral deposits containing potash (p. 116) and it was discovered during the war that some kinds of flue dust answer the same purpose.

It appears that sodium can to some extent replace potassium, and this partly explains the beneficial effect of dressings of sodium chloride in the case of some crops, especially mangels. More important than this, however, is the fact that salt helps to bring potassium compounds in the soil into an available form.

CHAPTER X

CLASSIFICATION OF ANIMALS—VERTEBRATES

IN one way or another agriculture is intimately concerned with animals. Domesticated forms are naturally of first importance, most of these being mammals or birds, together with one insect, the honey-bee, valued not only on account of its honey and wax, but as a pollinating agent (p. 36). Animals which are not domesticated are often enemies of the farmer, though some are friends. Among the former may be mentioned, as examples, rats and mice, many birds, a very large number of insects attacking crops or stock, ticks and mites, snails and slugs, parasitic worms (tape-worms, flukes, etc.) and microscopic animals (Protozoa) causing such diseases as red water and—in tropical Africa—fly-sickness (nagana). Beneficial animals are of equally diverse kind. Small carnivores, such as stoats and weasels, help to keep rats, mice, and voles in check; while such insectivores as mole and hedgehog destroy many noxious invertebrates. Most birds of prey account for large numbers of small injurious mammals, while bats and many birds are insectivorous. Frogs and toads prey on insects, slugs, and snails. Not a few insects, either as adults or larvae, and sometimes in both these stages of life, keep down pests belonging to their own class, and it is a familiar fact that spiders destroy innumerable insects. Among lower animals the earthworms are particularly notable for the services they render to agriculture, by way of comminution, mixing, and drainage of the soil.

A number of animals do both good and harm, in varying proportion, and for a given species the balance may be on

one side or the other according to differences in place, season of the year, or some other controlling factor. In such cases a supposed offender should receive the benefit of the doubt, though it would probably be justifiable to keep down its numbers. Ruthless extermination is usually bad policy, for to upset the balance of wild life is apt to result in unforeseen and often deplorable results.

CLASSIFICATION OF ANIMALS.—The principles already described (p. 76) in dealing with the classification of plants apply to animals as well. The following sub-kingdoms or phyla are of agricultural importance, and will therefore be described in outline.

I. VERTEBRATA (CHORDATA) or BACKBONED ANIMALS, including five classes:

1. **Mammalia,** to which belong most domesticated forms, e.g. horse, ox, sheep, goat, and pig: also many wild species, e.g. stoat, rats, mice, voles, mole, and hedgehog.
2. **Aves** (Birds), the inhabitants of the poultry yard, and a large number of wild birds.
3. **Reptilia** (Reptiles), e.g. lizards and snakes: of little importance in this country.
4. **Amphibia,** e.g. frogs and toads.
5. **Pisces** (Fishes).

II. MOLLUSCA, e.g. snails and slugs.

III. ARTHROPODA or JOINTED-LIMBED ANIMALS. Four classes are of more or less agricultural importance:

1. **Crustacea.** Prawns, shrimps, lobsters, crayfish, crabs, woodlice.
2. **Myriapoda.** Centipedes and Millipedes.
3. **Insecta.** Insects.
4. **Arachnida.** Scorpions, Spiders, Ticks, and Mites.

IV. ANNELIDA or SEGMENTED WORMS, e.g. Earthworms and Leeches.

V. NEMATHELMIA or ROUND WORMS.

VI. PLATYHELMIA or FLAT WORMS. Two important classes:

1. **Trematoda.** Flukes.
2. **Cestoda.** Tape-worms.

VII. PROTOZOA or ANIMALCULES. Innumerable microscopic forms.

All but the first of these phyla, together with some others, are conveniently spoken of collectively as INVERTEBRATA or BACKBONELESS ANIMALS, much in the same way as all plants except those producing seeds are lumped together under the name of CRYPTOGAMIA or SEEDLESS PLANTS (p. 87).

SYMMETRY OF THE BODY.—In all animals with which we are here concerned, except the Protozoa, the body possesses that kind of regularity known as **bilateral symmetry.** Like an irregular or bilateral flower (p. 78) the body is made up of corresponding right and left halves, each of which is a mirror image of the other. There is further a distinction between front (anterior) and back (posterior) ends, and also between upper (dorsal) and lower (ventral) surfaces. These differences have been evolved as adjustments or adaptations to the surroundings (environment). The anterior end goes first as the animal moves from place to place, and this, the most important part of the body, has been specialized into a head, containing the brain and most important sense organs, as well as the first part of the digestive tube, into which the mouth opens. The dorsal and ventral surfaces differ from each other because they have continually been exposed to unlike conditions, especially as regards light. As a general rule the dorsal surface is darker in colour than the ventral, which tends to make the animal inconspicuous when looked at against its natural surroundings, and this sort of colouration is **protective** in herbivorous forms such as the rabbit, which are thus to some extent hidden from their enemies; and **aggressive**

in carnivorous forms such as beasts of prey, which are in this way rendered less conspicuous to prospective victims.

Phylum **VERTEBRATA (CHORDATA).** Backboned Animals.—The body of a backboned animal may be described as a double tube, as will be apparent by examination of transverse and longitudinal sections (Fig. 53). The upper tube, or **neural canal**, is near the dorsal surface, and contains the **central nervous system**, of which the front part or **brain** occupies an enlargement of the neural canal situated in the brain-case or cranium. The brain is continued behind into the **spinal cord** or marrow, which is sheltered in the narrower part of the neural canal. This central nervous system is hollow, but the cavity within the spinal cord is extremely narrow.

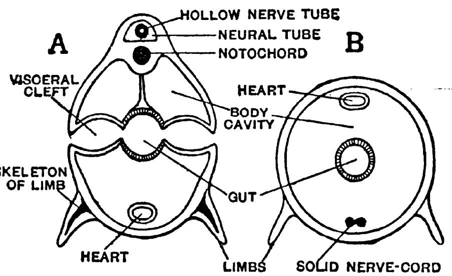


FIG. 53. VERTEBRATE (A) AND HIGHER INVERTEBRATE (B), IN DIAGRAMMATIC CROSS-SECTION

The larger ventral tube contains the bulk of the internal organs or viscera, such as the heart, lungs, stomach, intestines, and kidneys.

At a fairly early stage in the development of the embryo an elastic rod, the **notochord**, is formed in the partition between the two tubes, its pointed front end being below the middle of the brain. In some lower vertebrates the notochord persists throughout life, but as a general rule it is more or less replaced by a firmer **vertebral column**, divided into a series of joints or **vertebrae**, and thus rendered more flexible than if it were in one piece. In such

fishes as sharks the vertebral column is entirely composed of gristle or cartilage, together with fibrous material, but in higher forms than these it is more or less bony, and can then be called a backbone.

The existence of a notochord at some period of life is one of the leading characters of this phylum, which for this reason is often termed 'Chordata.'

Another important feature of vertebrate or chordate animals is the presence of **gill pouches** in the side of the throat at some stage in the life history, and these commonly communicate with the exterior by **gill slits.** They are present in adult fishes, and some amphibians, where the breathing organs (gills) are outgrowths from their walls. Water is taken in through the mouth, passing out again through the gill slits over the gills, which take up dissolved oxygen from it, at the same time getting rid of carbon dioxide as a waste product. The young or tadpoles of all amphibians possess gill slits and gills, but in most cases these disappear when the adult stage is reached. Reptiles, birds, and mammals never possess gills, though gill-pouches are present in the embryo and in some cases open to the exterior by gill-slits.

The three lowest classes of vertebrates are of no particular agricultural importance, so it will not be necessary to say much about them. **Fishes** have already been noted as a source of manure and nitrogenous feeding stuff (fish meal). Malarial diseases disseminated by mosquitoes hinder the agricultural development of tropical countries, and various small fresh-water fishes prey upon the aquatic larvæ of these pests. The most familiar examples of the **Amphibia** are frogs and toads, and as these destroy a great many slugs and noxious insects they rank as beneficial animals, and their presence in gardens should be welcomed. With regard to **Reptiles** it may be noted that lizards destroy many insect pests, while some of the snakes, including our native adder (*Pelias berus*), devour small rodent mammals injurious to agriculture.

CLASS AVES (BIRDS).

The large majority of birds devour pests, and are therefore beneficial to agriculture, and much harm has often been done by ruthless and unintelligent extermination. The agricultural value of common British birds is summarized in the following table.

The chief pests destroyed are insects, snails, and slugs; but birds of prey and owls do much to keep down the numbers of such injurious rodents as rats, mice, and field voles.

B=very beneficial; b=somewhat beneficial; H= very harmful; h=somewhat harmful; agri., agriculture; horti., horticulture.

I.	**Game Birds** (Galliformes)	B+h	Pheasant (*Phasianus colchicus*); Partridge (*Perdix perdix*); Red-legged Partridge (*Caccabis rufa*).
II.	**Pigeons and Doves** (Columbiformes)	b+H	Wood-pigeon (*Columba palumbus*), etc. Devour seeds, grain, and young plants. Do some good by destroying weed-seeds, and the Turtledove (*Turtur turtur*) is said to do more good than harm.
III.	**Rails** (Ralliformes)	B	Land-rail or Corn-crake (*Crex crex*).
IV.	**Gulls** (Lariformes)	B+h	Black-headed Gull (*Larus ridibundus*), etc.
V.	**Plovers** (Charadriiformes)	B or b	Golden Plover (*Charadrius pluvialis*); Lapwing, Peewit, or Green Plover (*Vanellus vanellus*); Stone Curlew (*Oedicnemus oedicnemus*), etc.
VI.	**Herons** (Ardeiformes)	b	Grey Heron (*Ardea cinerea*).
VII.	**Ducks and Geese** (Anseriformes)	h	Mallard or Wild Duck (*Anas boscas*); Grey Lag Goose (*Anser cinereus*), etc.
VIII.	**Falcons and Hawks** (Accipitriformes)	Mostly B+h	Peregrine Falcon (*Falco peregrinus*); Kestrel or Wind-hover (*Cerchneis tinnunculus*), etc. The Sparrow-hawk (*Accipiter nisus*), however, is b+H.
IX.	**Owls** (Strigiformes)	B	Barn Owl (*Strix flammea*); Tawny Owl (*Syrnium aluco*), etc.
X.	**Goatsuckers and Swifts** (Coraciiformes)	B	Goatsucker or Nightjar (*Caprimulgus europaeus*); Swift (*Cypselus apus*).
XI.	**Cuckoos** (Cuculiformes)	B+h	Cuckoo (*Cuculus canorus*) devours hairy caterpillars rejected by other birds.
XII.	**Woodpeckers** (Piciformes)	B	Green Woodpecker (*Gecinus viridis*); Greater and Lesser Spotted Woodpeckers (*Dendrocopus major* and *D. minor*).

XIII. **Perching Birds** (Passeriformes)		
(1) Crows	Various	Carrion Crow (*Corvus corone*), b+h; Hooded Crow (*C. cornix*), b+H; Jackdaw (*Coloeus monedula*), B+h; Magpie (*Pica pica*), B+h; Jay (*Garrulus glandarius*), B+h; Rook (*Trypanocorax frugilegus*), b+H.
(2) Starlings	B agri., b+H, horti.	Common Starling (*Sturnus vulgaris*).
(3) Finches and Buntings	Various	Bullfinch (*Pyrrhula europaea*), H; Chaffinch (*Fringilla coelebs*), b+h; Linnet (*F. cannabina*), b+h; Goldfinch (*Carduelis elegans*), b; Greenfinch (*Ligurinus chloris*), Hawfinch (*Coccothraustes vulgaris*), b+H; House Sparrow (*Passer domesticus*), b+H; Yellow Hammer (*Emberiza citrinella*), b; Corn Bunting (*E. miliaria*), b.
(4) Larks	B+h	Sky-lark (*Alauda arvensis*); Wood-lark (*A. arborea*), etc.
(5) Wagtails and Pipits	b	Pied Wagtail (*Motacilla lugubris*); Yellow Wagtail (*M. rayi*); Meadow Pipit or Titlark (*Anthus pratensis*).
(6) Creepers	B	Tree-creeper (*Certhia familiaris*).
(7) Nuthatches	b	Nuthatch (*Sitta caesia*).
(8) Tits	B	Blue Tit (*Parus caeruleus*); Coal Tit (*P. britannicus*); Great Tit (*P. major*).
(9) Thrushes	B+h, agri. b+H, horti.	Song Thrush (*Turdus musicus*); Missel Thrush (*T. viscivorus*); Fieldfare (*T. pilaris*), B; Redwing (*T. iliacus*), B; Blackbird (*T. merula*); Whin-chat and Stone-chat (*Pratincola rubetra* and *P. rubicola*), B; Wheat-ear (*Saxicola oenanthe*), B; Robin (*Erithacus melophilus*), B.
(10) Warblers	b, agri. b+H, horti.	Black-cap (*Sylvia atricapilla*); Garden Warbler (*S. hortensis*); Hedge Sparrow (*Accentor modularis*), B.
(11) Golden-crested Wrens	B	Gold-crest (*Regulus cristatus*).
(12) Wrens	B	Wren (*Troglodytes parvulus*).
(13) Flycatchers	B	Spotted Flycatcher (*Muscicapa grisola*).
(14) Swallows	B	Swallow (*Hirundo rustica*); House martin (*Chelidon urbica*); Sand martin (*Cotile riparia*).

The **Rook** and **Starling** are cases of birds which have increased out of proportion to the available amount of their normal food, and have therefore been driven to attack various crops. Such birds should be thinned out but not exterminated.

Domesticated Birds.—Fowls, guinea fowls, and turkeys,

are game birds belonging to the pheasant family. Our numerous races of fowl are probably all descended from the **red jungle-fowl** (*Gallus ferrugineus*), which somewhat resembles but is smaller than the game breeds, and ranges from India through South-east Asia and the East Indies. **Guinea fowls** are derived from a West African species (*Numida meleagris*), and **turkeys** are of North American origin, the ancestral form (*Meleagris gallopavo*) ranging from South Canada to Mexico. The **wild duck** or **mallard** (*Anas boscas*), which has a wide range throughout the northern hemisphere, represents the original stock from which domesticated ducks have been derived. The ancestor of our tame geese is the **grey lag** (*Anser cinereus*), which has a wide range throughout the Old World

Poultry-keeping is dealt with fully in another volume of this series.

Ostriches are well-known flightless birds, domesticated for the sake of the soft plumes from the tail and wings, which are pulled out every six or nine months. The most important ostrich-farms are in South Africa, but the industry is also carried on in South Europe, Australia, New Zealand, and the United States. Four species are recognized:

(1) **Common** or **northern ostrich** (*Struthio camelus*).—Skin of head and neck flesh-coloured; a horny shield on the top of the head. N. and W. Africa, Abyssinia, Arabia, South Palestine.

(2) *S. massaicus*. Differs from (1) in the absence of a horny shield. East Africa.

(3) *S. molybdophanes*. Skin of head and neck grey; a horny shield. Somaliland, Central Africa.

(4) **Southern ostrich** (*S. australis*). Differs from (3) in absence of horny shield. South Africa.

CLASS MAMMALIA (MAMMALS)

Mammals are the most important backboned animals from the agricultural point of view, including as they do man himself, most domesticated animals, and various wild

species that either help or harm the farmer. The more obvious distinctive characters of the class are: hot blood; hair; and secretion of milk for nourishment of the young.

An outline of the structure and functions of mammals has already been given (Chap. III), but a few details regarding limbs and teeth will help us to grasp the characters of the chief mammalian orders.

Limbs.—Unspecialized forms such as hedgehogs and rats are short-limbed and *plantigrade*, i.e. walking on the palms of the hands and soles of the feet; but rapidly moving types (dog, pig, sheep, horse) are longer in the limb and *digitigrade*, resting ont he ends of their digits and walking on tip-toe. There are also marked variations in the number of digits, of which the full complement is five, as in most monkeys and ourselves. It is convenient to number these digits from thumb or great toe onwards. A full set of digits is characteristic for primitive mammals, and also for cases where the extremities have complex duties to perform, of which the human hand is the most striking example. But where the limbs are devoted entirely or chiefly to rapid progression a reduction in number has taken place, the external digits being first affected. The ends of the fingers and toes may bear pointed claws, blunt hoofs, or flattened nails.

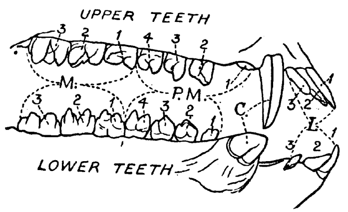


FIG. 54. TEETH OF PIG (from right side, reduced)

I, incisors; *C*, canines; *P.M.*, premolars; *M*, molars.

Teeth. (Fig. 54).—There are two successive sets, milk and permanent, the latter being more numerous. A full permanent set contains four different kinds of teeth—(*a*) front teeth or **incisors**; (*b*) tusks or **canines**; (*c*) **premolars**; (*d*) **molars.** The two last kinds are together known as back teeth, and molars differ from premolars in the fact that they have no predecessors in the milk set.

It is convenient to express the number of teeth by means of a **dental formula**, in which it is only necessary to consider one side, i.e. half the total number. The pattern formula is $\frac{3143}{3143}$, where the numerator of the fraction corresponds to the upper and the denominator to the lower teeth of either side. The four figures give, in succession, the number of incisors (3), canines (1), premolars (4), and molars (3), together making eleven teeth above and below each side=44 in all.

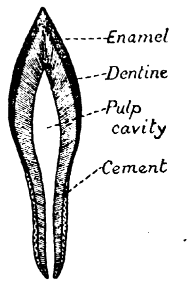


FIG. 55. INCISOR TOOTH
Longitudinal section; enlarged and diagrammatic.

A tooth consists of a **root** or **fang** imbedded in a **socket** (alveolus), and a **crown** which projects from the gum (Fig. 55). There is a central cavity filled with a soft substance (pulp) richly supplied with blood-vessels and nerves. Most of the tooth is made up of a hard material called **dentine** or **ivory**; the crown is covered by still harder **enamel,** and the root by a softer layer of bone (**cement**). The back teeth of horses and ruminants (ox, sheep, etc.) possess greatly specialized crowns folded in a more or less complex manner, the valleys between the folds being filled with cement (Fig. 56). As a result of wear a broad grinding surface is developed, and since the three constituent materials are of different hardness they wear away unequally so that a rough surface is maintained, much as in a grindstone.

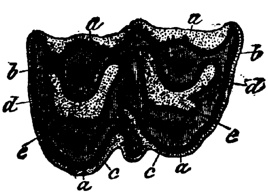


FIG. 56. CROWN OF OX'S MOLAR
a and *e*, Cement; *b*, enamel; *c*, dentine.

Five orders of mammals are of agricultural importance: (1) Ungulata, hoofed mammals; (2) Carnivora, beasts of prey; (3) Rodentia, gnawing mammals; (4) Insectivora, insect-eaters; (5) Chiroptera, bats.

(1) UNGULATA or HOOFED MAMMALS include ordinary

farm stock, and certain other forms of agricultural importance. They are all herbivorous, except the omnivorous swine. It is convenient to divide them into three sub-orders:

A. **Perissodactyles** or odd-toed forms, in which the middle or third digit is greatly developed and bilaterally ymmetrical. It is indeed the only one present in horse and ass, the species with which we are here concerned.

B. **Artiodactyles** or even-toed forms, commonly described as cloven-footed. The third and fourth digits are pominant and the axis of the limb runs between them. The other digits are more or less reduced. Here are included (*a*) **Swine**, omnivorous forms with cutting premolars and rounded projections (tubercles) on the crowns of the molars. They do not chew the cud and the stomach is simple. Short second and fifth digits are present, but these do not reach the ground, though they serve as 'stops' by which sinking into swampy soil is hindered. (*b*) **Ruminants** or cud-chewers, with ridges on the crowns of the back teeth and with complex stomachs. Those requiring notice here are: camel and lama; deer; oxen, sheep, goats, and buffaloes.

(*C*) **Elephants**, which are primitive in some respects but highly specialized in others.

A. **Perissodactyles.**—*Horse family* (Equidae)—This comprises horses, asses, and zebras. These are maned animals with bushy tails, and the large single toe of each limb bears a complicated hoof at its extremity. The dental formula is $\frac{3\cdot1\cdot4\cdot3}{3\cdot1\cdot3\cdot3}$. The crowns of the incisors are deeply pitted. As a general rule the canines (tushes) are only present in the stallion, and the first upper premolar (wolf tooth) may be absent altogether; in any case it is small, useless, and quickly shed. The back teeth possess complex crowns, adapted for grinding. The 'knee' of the fore limb is in reality the wrist, while the hock of the hind limb is the ankle.

The **horse** (*Equus caballus*) was domesticated by man at a very early period, and the original wild stock is almost

certainly extinct. There were probably more than one ancestral species. Horses are distinguished from asses by their long manes, broad flattish tails, broad hoofs; and the presence, usually, of a hard thickening of epidermis (chestnut) on the inner side of the hind-limb just below the hock joint. A similar patch is present above the knee on the inner side of the fore-limb both in horses and asses.

Many breeds of horses have arisen under domestication, the heavy ones, i.e. Shires, Clydesdales and Suffolks, being most important for agriculture. The cost of horse labour in British farming has usually been taken as a leading factor in calculating the cost of tillage operations. Before the Great War the average cost of a farm horse was about £40, and three shillings a day was considered a fair average for maintenance, including depreciation, but all post-war expenses are of course on a much higher scale. When steam engines came into use James Watt endeavoured to calculate their capabilities as compared with horses. He found that certain sturdy dray-horses could, when on their mettle, do work to the extent of 22,000 foot-pounds per minute, i.e. exert the force necessary to raise 22,000 lbs. one foot in that time, and adding 50 per cent for luck he coined the expression 'horse power' as the equivalent of 33,000 foot-pounds per minute. This is undoubtedly in excess of the capacity of any ordinary horse, and the expression is rapidly becoming obsolete.

The **ass** or **donkey** (*Equus asinus*) is obviously distinguished from the horse by its elongated ears and characteristic voice. The tail is cylindrical, the mane short and upright, the hoofs elongated and narrow. Hind chestnuts are absent, there is a dark stripe along the middle of the back, and also shoulder stripes. In all probability the ancestral form is a wild species (*E. taeniopus*) native to N.E. Africa. In proportion to their size donkeys are able to do more strenuous work than horses, besides which they are much hardier and cheaper to keep. They are employed to a considerable extent by

small farmers, smallholders, market-gardeners, etc. **Mules** are the hybrids produced by crossing horse and ass, the name being generally restricted to the progeny of jackass and mare, while the name **hinney** or **jennet** is given to the offspring of a stallion horse and a she-ass. In either case these hybrids are sterile among themselves, and in spite of assertions to the contrary there is no absolutely certain case of a fertile union between one of them and a horse or ass. Hinneys are not much employed, but mules are of extreme value in countries of mountainous character where proper roads have not been constructed. The following remarks of R. I. Pocock (*Standard Cyclopedia of Modern Agriculture*) summarize the points in their favour: "The value of mules as beasts of draught and burden cannot be overestimated. It has for long been fully realized in most parts of the world, although, in England, ignorance and prejudice have debarred their use on any extensive scale. The testimony of those who have had experience of both horses and mules is convincing as to the superiority of the latter animals where economy has to be considered and hard work done. They are longer lived, and able to withstand the effects of hard work for a greater number of years; they can be kept in vigour and health on coarser and cheaper food, and are therefore far less expensive to feed; they are hardier and able to resist extremes of temperature, especially of heat, of which horses are, comparatively speaking, intolerant; their narrow hoofs give them greater surefootedness than is found in horses, and enable them to pick their way with safety over mountain passes and by precipice edges which horses are afraid to traverse, or along which they cannot be led or driven without grave risk of disaster. Added to this mules have more caution, pluck, and perseverance than horses on difficult or dangerous ground, and are not less docile and tractable when managed with skill."

B. **Artiodactyla.**—(*a*) *Swine Family* (Suidae).—The British breeds of swine appear to be descendants of the wild pig or **wild boar** (*Sus scrofa*), a species which is widely

distributed in Europe, North Africa, and South-west Asia. It existed in Britain as late as the end of the sixteenth century, and very possibly later. In the wild state pigs are mostly to be found in thickly wooded swampy districts, digging up roots by means of the flexible snout, at the end of which is a hairless disc pierced by the nostrils. The bristly skin, large flapping ears, and cylindrical tufted tail are characteristic. Allusion has already been made to the limbs and teeth (p. 164 and 166). The canines are formidable tusks in the male, while in both sexes the crowns of the molars are *bunodont*, i.e. studded with rounded tubercles.

In some parts of the Continent wild pigs are serious agricultural pests, digging up and devouring root crops,

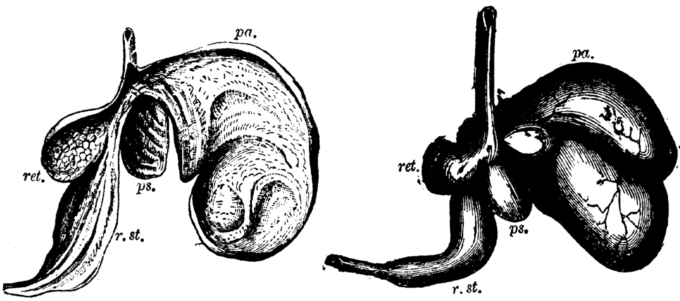


FIG. 57. STOMACH OF SHEEP

External appearance on right, cut open on left. *pa.*, paunch; *ret.*, reticulum; *ps.*, psalterium; *r. st.*, rennet stomach.

and also playing havoc with leguminous crops and cereals. It is worth noting that swine, whether wild or tame, are not the uncleanly creatures commonly supposed, but they have too often been kept under filthy and insanitary conditions.

(*b*) RUMINANTS.—As compared with swine this large and important group of even-toed Ungulates comprises herbivorous forms in which the back teeth are *selenodont*, i.e. provided with curved ridges instead of tubercles. The large stomach is of complex structure, in relation to the habit of rumination or 'chewing the cud.' In an ox or sheep, for example (Fig. 57), it consists of four chambers:

(1) the **paunch** (rumen), which is by far the biggest subdivision, and communicates by a large opening with (2) the **honey-comb stomach** (reticulum), which receives its name from the fact that its lining is raised into folds arranged like the cells of a honeycomb; (3) the **manyplies** (psalter, omasum), so named because its lining is raised into numerous flattened folds like the leaves of a book; (4) the **rennet stomach** (reed, abomasum), where the gastric juice is secreted. The food is cropped, without being chewed, and when swallowed passes for the most part into the paunch, but also, to some extent, into the honeycomb stomach, which also has the special function of storing liquid. It then undergoes a slow process of churning to and fro between these two chambers, the saliva with which it is soaked exerting a softening and dissolving action, while at the same time the cellulose is partly converted into sugar by the action of bacteria. Successive portions of the softened and partly digested food are then returned to the mouth as 'cud,' and are thoroughly chewed and still further exposed to the action of saliva. The return of food to the mouth, comparable to vomiting, can only take place when the paunch is fully distended. The food, now well chewed, is swallowed a second time, and passes along a muscular groove into the manyplies, which serves as a strainer; finally reaching the rennet stomach where it is subjected to the action of the gastric juice.

1. *Camel Family* (Camelidæ).—Camels are large long-legged ruminants of great importance for transport and military purposes in arid regions. One or two humps are present, and these may be regarded as an emergency store of food. The extremities possess two digits only (third and fourth), and these are provided with large elastic pads enabling progression on hot sand without discomfort. The dental formula is $\frac{1133}{3123}$, and the third chamber of the stomach (manyplies) is rudimentary. The lining of the paunch is folded into pouches with openings capable of closure, and serving for the storage of water.

There are two species of camel, neither of which is known

to exist in the wild state, the so-called 'wild' camels being almost certainly feral, i.e. animals which were formerly domesticated but have run wild. The **Bactrian** or **two-humped camel** (*Camelus bactrianus*) is only to be found in the desert regions of Central Asia, while the **one-humped camel** (*C. dromedarius*), originally native to Africa and Arabia, has been introduced into India, Australia and North America. Of the latter species a number of distinct breeds exist, the name dromedary being specially applied to the swifter kinds. The natural food of camels chiefly consists of the leaves and twigs of trees and shrubs, these being often of thorny and unpromising character; but such grazing is usually supplemented by rations of green fodder, hay, grain and cake.

The following remarks on the camel as a transport animal are quoted from the War Office Manual on *Animal Management*: 'As a transport animal the camel can, under suitable conditions, carry 250 to 450 lbs. twenty miles daily, and this must be looked upon as the limit of his normal powers when properly cared for. It is well to keep this in mind, for the animal's virtues are such that it is easy to overtax him unwittingly. Patient to a degree, enduring hunger, thirst and pain with a stoical courage above all others, the first sign that a camel may give that he is being asked to do the impossible is to drop down dead, on which account he has been classed as "delicate." The one point on which a camel may be fairly regarded as delicate is, that he is peculiarly susceptible to changes of climate and surroundings. You cannot, for instance, work a desert camel successfully in the hills, or a delta camel in the desert; but if properly selected and cared for they make excellent transport, are not more difficult to deal with than other animals, and on occasion are capable of a sustained effort which cannot be accomplished by any others. They are, however, unintelligent; they cannot be taught much, but are willing machines and must be driven with care and judgment.'

The South American **lama** (*Lama lama*) and **alpaca**

(*L. pacos*), are closely related to the camel, but humpless and of smaller size. The dental formula is $\frac{1123}{3123}$.

The former is used as a pack animal in the Andes, while the latter is valued for its long fine hair. Both are probably derived from the **huanaco** (*L. huanacos*) a wild South American species.

2. *Deer Family* (Cervidae).—Although the second and fifth digits are greatly reduced, being much smaller than in the pig, their tips are generally visible externally and bear very small hoofs. In nearly all cases the male carries defensive weapons or antlers on the head, these being bony outgrowths from the skull which are shed annually. There are no upper incisors and usually no upper canines, the typical dental formula being $\frac{0033}{3133}$. All four chambers of the complex stomach are well developed. The three species most familiar in Britain are the **red deer** (*Cervus elaphus*), **fallow deer** (*C. dama*), and **roe deer** (*Capreolus capraea*). They are all capable of damaging crops to a considerable extent, and are also apt to work mischief in woods and plantations. The **reindeer** (*Rangifer tarandus*), remarkable for the possession of antlers by both sexes, has a wide distribution through the colder parts of the northern hemisphere, and is of great importance as a domesticated animal to some of the more primitive peoples.

3. *Ox Family* (Bovidae).—The oxen, sheep, and goats included in this family are the most important mammals for agriculture, and also the most highly specialized of the even-toed hoofed forms. The third and fourth digits are well developed, while the second and fifth are reduced to insignificant vestiges. The head in both sexes typically bears horns that are not shed periodically, like the antlers of deer, and differ from these in structure. Each of them consists of a hollow horny sheath supported by a 'horn core,' which is an outgrowth from the frontal bone. The dental formula is $\frac{0033}{3133}$, and all four chambers of the complex stomach are fully developed.

The various breeds of European **oxen** (*Bos taurus*) differ

from one another in colour and various other respects, some of them being hornless or polled, e.g. Aberdeen Angus, Galloway, and red poll. The much debated question of their origin is discussed in another volume of this series. At least one extinct species, the small long-faced **Celtic shorthorn** (*Bos longifrons*), has contributed to the formation of British breeds. The **humped cattle** or **zebus** which take their place in India are of quite different ancestry, and the extinct species from which they are descended (*Bos indicus*) is well known. The long-haired humped **yak** (*Bos grunniens*) of Tibet is quite distinct from these.

Closely related to the preceding is the long-horned **Indian buffalo** (*Bos bubalus*), which has been domesticated for agricultural purposes, and is met with throughout India, Burma, and most of the Malay region; also in Egypt, Asia Minor and Italy.

The domesticated breeds of European **sheep** (*Ovis aries*) cannot be traced back to wild ancestors with any certainty. Most of them are polled, and when horns are present, as in the mountain breeds, they are usually possessed by the male only. Both sexes are horned in the Dorsets. Sheep differ from oxen not only in size but in certain structural features. The horns, when present, tend to be twisted or spirally coiled; a curious bottle-shaped gland opens between the toes in each foot, its use being to secrete an odoriferous substance that helps a strayed individual to follow the tracks of its flock; and the female has two teats instead of four.

There are many breeds of sheep besides those familiar in this country, the most notable being the **merino**, esteemed for the length and fineness of its wool. Originating in Spain it is now to be found in many parts of the world, including South Africa, Australia, and America.

Domesticated goats (*Capra hircus*) are largely derived from the **Persian wild goat** (*C. oegagrus*), which has a wide range in West Asia, and is also found in Crete and one or two other Greek islands. Goats differ from sheep in the

character of the horns, which are backwardly curved and not twisted, though to this there are exceptions, as in the case of the Angora breed. Here, however, the spiral is of corkscrew kind. The peculiar glands described for sheep are never present in the hind feet. The male is characterized by a strong and unpleasant smell, and also by the possession of a beard, though this may also be present in the female.

Goats can be recommended to those who desire a private milk supply, but are not in the position to keep a cow. The milk is richer and more digestible than that of the cow, the period of lactation varies from six months to a year, and the yield may be anything from a quart to a gallon per day. The butter is not much in favour owing to its absence of colour, but goat's milk is used for the manufacture of a number of much-esteemed Continental cheeses, among which the most noted are Mont d'Or, Levroux, Sassenage, and St. Marcelin.

Cashmere and Angora goats are valued on account of their hair, that of the latter being known as *mohair*. The **cashmere** or **shawl goat** is a native of Tibet, but has been successfully introduced into France. The **Angora goat,** originally from Asia Minor, is now to be found in South Africa, Australia, New Zealand, and the United States (chiefly California and Texas).

Goats, being waste users, are not costly to keep, but require a good deal of attention and are very destructive to shrubs and young trees.

C. **Elephants** (*Proboscidea*).—These are distinguished by their large size and their vertical pillar-like legs terminating in the full number of digits, which, in each foot, are united with an underlying elastic cushion. The muscular flexible proboscis into which the snout is drawn out is an efficient grasping organ. Canine and lower incisor teeth are absent, and upper incisors are represented by a pair of long curved tusks that grow throughout life, and are practically devoid of enamel. A series of six large grinding teeth is developed on each side

of upper and lower jaw. The total number of such teeth is twenty-four, but only one or two are in place at the same time in each side of either jaw. They are massive and of complicated structure, and their crowns are transversely ridged.

The **Indian elephant** (*Elephas indicus*), in spite of its uncertain temper, has been pressed into the service of agriculture, especially for transport purposes, being capable of carrying a load of 800 lbs. In India and Ceylon it is also employed in clearing ground for the establishment of tea plantations. The less docile **African elephant** (*E. africanus*) has been used, to a certain extent, for agricultural work in the Congo.

(2) CARNIVORA or BEASTS OF PREY pursue and devour other animals, and their structure is adapted to this mode of life. They are more or less digitigrade, and each foot possesses not less than four digits terminating in claws. The incisors are small, the canines in the form of tusks, and some or all of the back teeth are provided with cutting crowns. The last upper premolar and first molar on each side (carnassial or flesh teeth) are much enlarged and work against each other like the blades of a pair of shears. The carnivores of most agricultural importance are dog, fox, cat, and members of the weasel tribe.

Domesticated **dogs** (*Canis familiaris*) are probably descended from wild forms related to existing wolves and jackals. The very numerous and widely differing breeds have been brought into existence by artificial selection, and such of these as most nearly resemble the original stock are grouped together as 'wolf-like' dogs, these including the **old English** (bob-tailed) **sheep-dog**, and the **collie** or **Scottish sheep-dog**. The dental formula is $\frac{3142}{3143}$, and the last two molars both above and below have broad crowns suited for crushing, not for cutting. Wolves and wild dogs are gregarious, living in packs that hunt down and track their prey by scent.

The **common fox** (*Canis vulpes*) is closely related to the

dog, but is of slighter build, with shorter legs and larger ears. The long bushy tail and reddish brown colour of the upper parts are also distinctive characters. Foxes are not gregarious, and live in burrows during the day. Although destroyers of game and poultry they render good service to agriculture by keeping down rabbits and the smaller rodents, and also devour many insect grubs.

The domesticated **cat** (*Felis domesticus*) is probably descended from more than one wild species, suggested ancestors being the **European wild cat** (*F. catus*)), still to be found in Scotland, and the **Egyptian wild cat** (*F. ocreata*). It is much more highly specialized as a flesh-eater than the dog. When not in use the sharp claws are drawn back into protective sheaths, from which they can be shot out to seize prey. The jaws are short and strong, and the teeth reduced in number, the dental formula being $\frac{3131}{3121}$. All the back teeth have cutting crowns. The rough tongue is used for rasping flesh. Cats are solitary animals, and stalk their prey by sight, finally securing them by a sudden spring. Being expert climbers they are a terror to small birds. By keeping down rats and mice they benefit agriculture considerably.

(3) RODENTIA or GNAWING MAMMALS include rats, mice, voles, rabbits, and various other small creatures, all more or less harmful to agriculture. They are either herbivorous or omnivorous, and are distinguished by the possession of curved chisel-edged incisor teeth, two above and two below, which grow continuously throughout life and therefore have to be kept worn down to a convenient length by the constant gnawing or nibbling of hard substances. That they are kept sharp depends on the fact that they are thickly coated with enamel in front, and this wears down less quickly than the softer dentine behind it. Canines are absent, and the crowns of the premolars and molars have rough crowns. Rodents are comparatively defenceless and have numerous enemies, but their extraordinary fecundity secures them against extermination.

We are only concerned here with two families:

(*a*) Muridae—rats, mice, and voles. (*b*) Leporidae—hares, and rabbits.

(*a*) *Muridae.*—Rats and mice are omnivorous forms, with an elongated body, pointed snout, and long scaly tail. The crowns of the back grinding teeth are studded with small tubercles. Relatively large species are 'rats,' and relatively small ones 'mice.' Eyes and ears are large, and the thumb is much reduced in size. Our three most familiar pests of the kind are the black rat, the brown rat, and the house mouse, all of Asiatic origin. The black rat (*Mus rattus*) was probably introduced into this country at the time of the Crusades, and was once a serious land pest, but except here and there is now practically extinct, having been unable to survive competition with the brown species. It is, however, the commonest kind of ship rat, probably because it is a much better climber than the latter. An adult specimen usually weighs less than eight ounces.

The **brown rat** (*Mus decumanus* or *Rattus norvegicus*) migrated to this country in the early part of the eighteenth century from temperate Asia, and is now a serious pest in many countries. Our own rat population was estimated in 1909 as being at least forty millions. Brown rats are larger and more powerful than black ones, adults usually weighing from fourteen to seventeen ounces. Though less expert as climbers they excel as swimmers, and are always attracted by the neighbourhood of water.

The **house mouse** (*Mus musculus*) has inhabited this country from very early times, and is a commoner house pest than the brown rat, but is also quite frequent out of doors, often being mistaken for the long-tailed field-mouse.

Damage done by rats.—This is of the most varied kind, and so well known that detailed description is unnecessary. 'To agriculture in all its branches the brown rat is especially a most dangerous pest. Grain of all sorts is undoubtedly the chief and favourite food of the rat. Before the grain is sown, in every stage of its growth, and after the harvest, wherever it is stored or in whatever form

it is used, it is subject to attack by this animal. An enormous toll is thus levied upon farmers, millers, grain merchants and consumers—a toll which is difficult to appraise, but which, in the case of the farmer, must often be equal to rent and taxes combined.' (M. A. C. Hinton, *Rats and Mice as Enemies of Mankind*, pp. 14-15.)

Various attempts have been made to calculate the money value of the damage effected by rats. Assuming that there are 40,000,000 of these pests in Britain, and that each of them costs a farthing a day to keep, the annual total works out at considerably over £15,000,000, and to this must be added the heavy expenses incurred by attempts to keep down the rat population. No account is taken here of the enormous amount of damage caused by ship rats.

Rats are also responsible for the spread of serious diseases, particularly plague, of which the germs are borne by rat-fleas. Foot-and-mouth disease and influenza of horses are also possibly disseminated by rats. Mention must further be made of the minute thread-worm, *Trichina spiarlis*, which infests the muscles of the rat, and if diseased individuals are eaten by pigs, they are caused to suffer in the same way. Pork may thus contain this parasite, in an encysted form, sometimes to be passed on to human beings.

What has been said about the damage caused by rats, and the diseases spread by them, applies also to mice, broadly speaking.

Preventive Measures against Rats and Mice.—Something can be done by protection of natural enemies, such as owls, kestrels, weasels, and stoats. Much more is possible by way of making buildings, especially those used for storing food-stuffs, rat-proof and mouse-proof; while receptacles for food and refuse ought to be so constructed as to keep out these pests. Ricks and granaries should be built on rat-proof piles. The possibility of rats passing from the sewers into drains and water pipes should be excluded, and rubbish dumps should not be permitted. Port authorities

fumigate ships, and also check the interchange of pests between these and the land; measures which should be made universal and extended to river and canal craft.

Destruction of rats and mice.—Every method should be employed as opportunity offers. Terriers, aided by ferrets, account for a great many rats, especially at threshing time; cats are sometimes good ratters, but are, of course, of much greater importance as regards mice.

Traps of various type can be employed with success, and it is particularly important to vary the bait, and to make it of different nature from the food available in the locality.

Poisons are commonly employed to cope with rats and mice, especially preparations of phosphorus, arsenic, and strychnine, but as these are a serious danger to human beings and domestic animals, their general use cannot be recommended. Small pieces of bread soaked in liquid extract of squill (*Scilla maritima*), diluted with an equal volume of milk, furnish a very destructive bait, which is not open to this objection. The same is true for barium carbonate, one part of which mixed with eight parts of oatmeal, and kneaded into a stiff dough with a little water, often proves very effective.

Burrows can be dealt with effectively by **fumigation** with chlorine, sulphur dioxide (also used on ships), or the vapour of carbon bisulphide. After burrows have been treated gas-tar should be run in.

Different kinds of **virus**, prepared by making cultures of certain bacteria, have been used with varying success. But they are expensive, difficult to standardize, liable to deteriorate, and need expert handling. They claim to be harmless except as regards rats and mice, but further evidence as to this is necessary, at any rate in some cases. Small doses confer immunity, and are worse than useless.

The **wood-mouse** or **long-tailed field-mouse** (*Apodemus sylvaticus*) is somewhat larger than the house-mouse, with longer tail and larger ears and eyes (Fig. 58). It is a pest both to agriculture and horticulture.

Voles are often confounded with rats and mice, but are

more stoutly built, with blunt snout and small ears, and a short hairy tail. The back teeth have long crowns marked with a pattern of alternating triangles. Best known in this country is the **field vole** (*Microtus hirtus*),

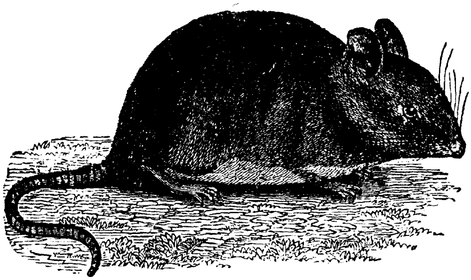


FIG. 58. LONG-TAILED FIELD MOUSE (*Apodemus sylvaticus*)

often called the short-tailed 'field-mouse' (Fig. 59), replaced in the Scottish Highlands by the **Highland field-vole** (*M. agrestis*). Both these species are burrowing forms which do much damage to all kinds of crops, and sometimes multiply to an alarming extent, especially in places where their natural enemies have been ruthlessly hunted down.

(*b*) *Leporidae* (hares and rabbits) include rodents of much larger size than those just described. There are

FIG. 59. SOUTHERN FIELD VOLE (*Microtus arvalis*
A pest on Continent; closely resembles *M. agrestis*.

two small incisors in the upper jaw immediately behind the large ones: other characters are the elongated hind-limbs, long ears, and short tail. The **rabbit** (*Lepus cuniculus*) differs from the hare by its habit of living in large

communities which excavate extensive burrows as a protective measure, while the young are born in a very imperfect condition. The damage done by this pest, and the measures employed to keep down its numbers are too well known to need description.

(4). Insectivora or Insect-eating Mammals include Hedgehogs, Shrews, and Moles, all of which are beneficial to agriculture and horticulture. They are less specialized than rodents, especially as regards their teeth. There are twelve incisors and four canines, and the crowns of the back teeth are studded with sharp points suitable for crushing insects and other small creatures. The snout is narrow and sensitive, being thus well adapted for exploring crannies and crevices in pursuit of prey. The tail is short.

The **hedgehog** (*Erinaceus europaeus*) possesses numerous spines intermixed with ordinary hairs on the back and flanks, and these afford efficient protection against most enemies when it rolls up into a prickly ball. Its varied bill of fare includes mice and voles, snakes, frogs, snails, adult insects and larvae, earthworms, fallen fruit and succulent roots. The animal does some damage to agriculture by devouring eggs and attacking chickens, but is in the main beneficial and deserves protection.

Shrews are small creatures sometimes mistaken for mice, but easily distinguishable from these by their slender snout and musky smell, and characteristic teeth. There are, however, no lower canines. The most familiar British species is the **common shrew** (*Sorex vulgaris*), which is, like all its kind, purely carnivorous, destroying large numbers of insect pests, snails and slugs (Fig. 60). It is extremely pugnacious and often attacks small vertebrates of various kind.

The **mole** (*Talpa europaea*) is beautifully adapted to a burrowing underground life, as seen in the spade-like hands, and short velvety fur, in which the minute eyes are buried. There are no external ears. Although molehills are sometimes unwelcome on grass land, and particularly on lawns, the burrows promote drainage, while these animals devour

vast numbers of underground insect larvae, such as leather jackets, wire-worms, and grubs, and also prevent the undue increase of earth-worms.

(5). CHIROPTERA or BATS are closely related to the Insectivora in structure, and in the nature of their food,

FIG. 60.—GARDEN SHREW (*Crocidura aranea*)
Similar to *Sorex vulgaris* of Britain.

but are greatly specialized for flight. A flying membrane is present in the form of a fold of skin extending between the fore- and hind-limbs, and also between the latter and the tail. The fingers are greatly elongated and support the

flying membrane, but the thumb is short and bears a hook-like claw. They actively pursue moths in the dusk, and therefore help to keep down the numbers of many destructive caterpillars. There are rather more than a dozen British species, of which the commonest is the **pipistrelle** (*Vesperugo pipistrellus*).

CHAPTER XI

CLASSIFICATION OF ANIMALS

INVERTEBRATES.—MOLLUSCA, ARTHROPODA, ANNELIDA, NEMATHELMIA, PLATYHELMIA, PROTOZOA

Phylum **MOLLUSCA**

MANY familiar animals are included in this subdivision of the animal kingdom, e.g. cuttle-fishes; snails and slugs; oysters, cockles, and mussels. The body is unsegmented, i.e. it is not divided into a series of rings or segments as in centipedes and earthworms. On the ventral side of the body is a muscular expansion called the **foot**, very clearly seen in a crawling snail. A **shell** is commonly but not always present, and this may be in one piece (univalve) as in snails, or two pieces (bivalve) as in oysters.

The phylum is divided into three chief classes. (1). Cephalopoda, including the cuttle-fishes and pearly nautilus—all marine. (2). Gastropoda, embracing a vast assemblage of snails, mostly marine, but some fresh-water and others living on land: also sea-slugs and land-slugs. (3). Lamellibranchia, comprising marine and fresh-water bivalves.

Class Gastropoda.—This is the only group of molluscs that needs consideration here, more especially as regards land-snails and land-slugs. These forms possess a distinct head, bearing two short and two long feelers or tentacles, the latter with eyes at the tip. Land-snails are protected by spiral shells into which the body can be withdrawn; while land-slugs either have a minute conical shell or no shell at all. The food consists of all sorts of vegetable

substances, which are attacked by a peculiar **rasping organ** (odontophore). This consists of a sort of hump on the floor of the mouth-cavity, over which is stretched from front to back a horny ribbon, the **radula**, studded with innumerable minute teeth (Fig. 61). The roof of the mouth-cavity is armed in front with a curved saw-edged **upper jaw** opposed to the radula. When in use the rasping organ protrudes from the mouth, and by means of small muscles the radula is moved forwards and backwards like a chain-saw. It is gradually worn away by continuous use, but this is compensated by forward growth, like that of a finger-nail from its base.

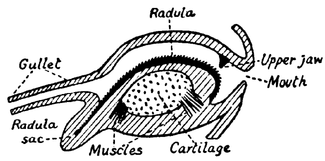


FIG. 61. ODONTOPHORE OF SNAIL
Longitudinal vertical section. Diagrammatic and enlarged.

The two most familiar pests belonging to the class are the garden snail (*Helix aspersa*) and the grey field-slug (*Limax agrestis*) (Fig. 62). These and allied forms can be kept down by drainage, the use of artificial manures instead of dung and other bulky organic substances, and dressings of soot and lime, salt and lime, lime and caustic soda, or powdered coke. Two or three successive dressings are necessary, as for a considerable time the abundant slime

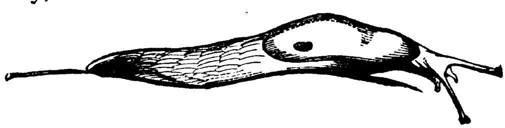


FIG. 62. FIELD-SLUG (*Limax a restis*)

exuding from the skin of these pests serves as an efficient protection.

PHYLUM **ARTHROPODA**. JOINTED-LIMBED ANIMALS.

This phylum comprises a vast assemblage of animals in which the body is made up of a series of rings or segments

bearing a varying number of jointed limbs or appendages. Four classes are of more or less interest to the farmer and fruit-grower :—Crustacea, Myriapoda, Insecta, and Arachnida.

Class Crustacea

Here are included a great variety of forms, most of which are aquatic, such as prawns, shrimps, lobsters, crayfish, and crabs ; but the woodlice live on land and attack various plants. The body is divided into head, thorax, and abdomen. The head bears two pairs of feelers (antennae) and compound eyes, each consisting of a number of visual elements optically distinct and marked externally by the presence of square or polygonal facets. Some of the head-limbs are modified into jaws that work from side to side. The appendages of the thorax are mostly concerned with locomotion, but some of the anterior ones are modified into jaws. The abdominal limbs commonly co-operate with those of the thorax for locomotor purposes. The larger aquatic Crustacea breathe the air dissolved in water by means of delicate outgrowths known as gills, which may be present on the thorax or abdomen, or on both.

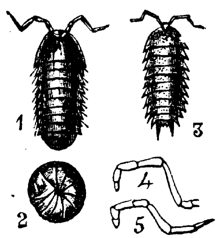


FIG. 63. WOODLICE
1 and 2, *Armadillo vulgaris*; 3. *Porcellio scaber*; 4, antenna of Oniscus; 5, antenna of Porcellio.

Woodlice. (Fig. 63).—These terrestrial Crustacea are the only members of their class requiring mention. They damage fruit and mushrooms, attack the roots and crowns of many plants grown under glass, and also those of strawberries. Most of their abdominal limbs are modified into delicate plates able to breathe moist air and provided with firmer covers. The three commonest British species are the **grey woodlouse** (*Oniscus asellus*), the rather larger **blue woodlouse** (*Armadillo vulgaris*), and the **brown woodlouse**

(*Porcellio scaber*). The two last can roll themselves up, hence their American name of 'pill bugs.' Woodlice are easily trapped by rotten fruit, pieces of potato, cucumber, and the like, especially when hollowed out.

Class Myriapoda

This class includes Centipedes and Millipedes, elongated land forms with a distinct head followed by a trunk made up of a varying number of similar segments. The head bears a single pair of **feelers** (antennae) and three pairs of **jaws**, while simple eyes (ocelli) or groups of these are often present. Numerous pairs of jointed **legs** are attached to the segments of the trunk. The breathing organs consist of delicate branching **air-tubes** (tracheae) communicating with the exterior by a series of small holes (spiracles or stigmata) on the sides of the body.

Myriapods are divided into five orders, of which only two are of agricultural importance, i.e. the Chilognatha or Millipedes, and the Chilopoda or Centipedes.

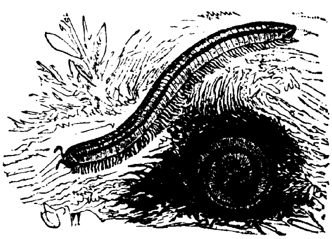


FIG. 64. COMMON MILLIPEDE (*Julus terrestris*), enlarged

Millipedes are plant-eating forms commonly known as false wire-worms, which, attack the underground parts of various cultivated plants (Fig. 64). The body is cylindrical, and each of the trunk segments—except the first three—bears two pairs of weak legs attached close together on the under side, and possesses a pair of spiracles.

These pests may be kept down by applications of soot or lime, and can also be trapped in scooped-out turnips, mangels or beets sunk just below the surface.

Centipedes are active carnivorous forms that prey upon various pests and are therefore beneficial. The body is

flattened from above downwards, and each trunk segment bears a pair of strong legs with widely separate bases (Fig. 65). A pair of spiracles is present on every other segment

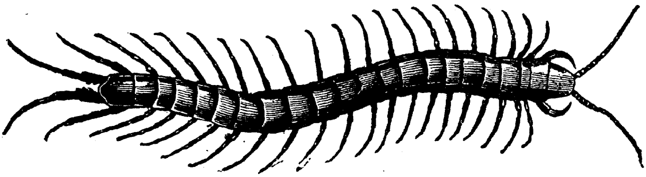


FIG. 65. CENTIPEDE (*Scolopendra morsitans*)
A tropical species.

of this region. The first trunk segment is fused with the head and bears a pair of poison claws.

Class Insecta. Insects

This immense assemblage of animals includes a very large number of pests, some of which attack plants, while others are injurious to stock. Fortunately, however, many insects are beneficial. Most members of the class are thoroughly adapted to life on land and in the air, but a few inhabit fresh water during the whole of life, while others—e.g. mosquitoes—are aquatic during the early stages of their existence.

Insects have evolved from members of the centipede order by shortening and specialization of the body. There are three distinct and successive regions—head, thorax, and abdomen. The **head** consists of a number of segments —probably six or seven—intimately fused together and bearing a pair of **feelers** (antennae), three pairs of **jaws**, and often a pair of large **compound eyes. Simple eyes** (ocelli) may be present in addition, while in some cases these are the only visual organs.

From a practical point of view it is convenient to distinguish between 'mandibulate' insects, with biting mouth-parts, and 'haustellate' ones in which these parts are adapted for sucking and sometimes for piercing as well.

But both types may be combined, as in bees; while in butterflies and moths the young form is mandibulate and the adult suctorial. In all cases there are three pairs of jaws, easily recognizable in primitive mandibulate insects such as the Cockroach (Fig. 66). Here the first and second pairs of jaws—**mandibles** and **1st maxillae**—work from side to side in a space bounded in front by the **upper lip** (labrum) and behind by the **lower lip** (labium), the latter consisting of the third pairs of jaws—**2nd maxillae**—partly fused together. Small feelers are borne by the

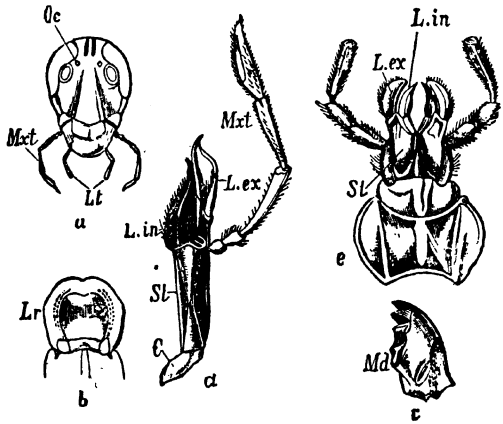


FIG. 66. COCKROACH (*Stylopyga orientalis*), enlarged to various scales.

a, Front view of head, showing large kidney-shaped compound lateral eyes; *Oc*, simple eyes; *Mxt*, maxillary palps; *Lt*, labial palps; *b*, upper lip or labrum (*Lr*); *c*, a mandible (*Md*); *d*, a first maxilla; *C* and *St*, basal joints; *L. in.* and *L. ex.*, internal and external lobe; *Mxt*, maxillary palp; *e*, lower lip (labium) formed by partial fusion of second maxilla; *St.*, basal joint; *L. in.*, and *L. ex.*, internal and external lobes; labial palps, right and left.

1st and 2nd maxillae, and these are known, respectively, as maxillary and labial palps.

The insect **thorax** consists of three partially fused segments, technically known as prothorax, mesothorax, and metathorax, each of which bears a pair of jointed **walking legs.** The presence of six legs is distinctive, and the name Hexapoda is sometimes given to the class on

this account. There are usually two pairs of thoracic **spiracles**. The thorax of an average insect also bears two pairs of **wings**, fore and hind, respectively attached to the mesothorax and metathorax. These wings differ greatly in character in the different orders of insects. Some forms are wingless, in the simplest cases because these organs were never developed, and in other cases as the result of reduction. Sometimes one pair is suppressed, usually the hind-wings, as in flies (Diptera).

The **abdomen** of an insect is the least specialized region, and typically consists of ten segments less intimately united than those of the head and thorax. Each of the first eight (or nine) possesses a pair of **spiracles**. In adult insects abdominal limbs are only present at the posterior end, and these may be specialized as feelers (cerci), stings, egg-laying structures (ovipositors), and copulatory organs.

The internal structure of an insect is very complex. The digestive organs consist of an **alimentary canal** divided into several regions, and opening externally by the mouth on the under side of the head, and the anus at the tip of the abdomen. There are large **salivary glands** that open by a slender duct into the under side of the mouth cavity. Breathing is effected by delicate branching **air-tubes** that traverse all parts of the body and communicate with the exterior by the **spiracles**. The sexes are distinct, and the reproductive organs complex.

The **heart** is a narrow tube placed near the upper side of the body and communicating with a complicated system of blood-spaces.

The **nervous system** is a double cord situated near the under side of the body and swollen into paired **ganglia** from which nerves are given off. In front the cord forks and becomes continuous with a **nerve-ring** that encircles the gullet and is thickened dorsally into a pair of **cerebral ganglia** serving as a brain. They are of large size, especially in the more intelligent insects, such as bees and ants. The eyes, feelers, and palps are the most important but not the only sense organs.

Considering that insects are the most important of all pests, some knowledge of their **life-history** is essential, for this alone renders it possible to devise effective preventive and remedial measures. In some forms (Ametabola) the just-hatched insect differs but little from the adult except in size; in others (Hemimetabola) there is a certain amount of difference: while in others again (Holometabola) the life-history is made up of stages which differ greatly from one another. As an example of the last may be taken the familiar case of a **moth** or **butterfly** (Fig. 67). The egg hatches out into a worm-like **caterpillar**, extremely unlike its parents, and known—as in all such cases—as a **larva**. It is essentially the feeding stage of life and is provided with biting mouth-parts that enable it to devour vegetable food. The caterpillar grows steadily in size, casting its skin from time to time, and ultimately passes into a quiescent stage, known as a **chrysalis** or, to use the broader term, a **pupa**. Within the firm investment of the pupa the body undergoes revolutionary changes, remodelling it into the form of the adult, or **imago**, which finally emerges as a perfect moth or butterfly.

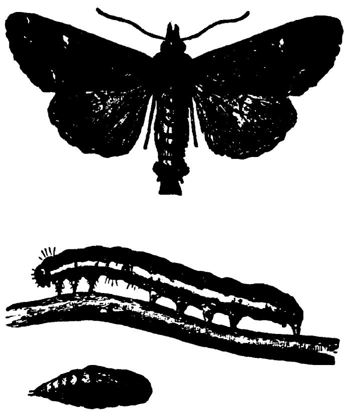


FIG. 67. CABBAGE MOTH (*Mamestra brassicæ*), WITH CATERPILLAR AND PUPA

In framing a plan of campaign against a pest form with a complex life-history like this there are obviously various lines of attack, and the weakest link in the chain must be sought. Insects are so extraordinarily fertile that every effort must be made to prevent egg-laying, but no uniform method can be

prescribed. Examples of the chief types of procedure will be given in the sequel.

There is no pupa stage in the Hemimetabola and Ametabola, but in some of the former there is a marked difference between the just-hatched young and the adults.

Classification of Insects.—Since something like 250,000 species have been described and named, the task of arranging these into groups is no easy one, and it is not surprising that experts differ in their methods. The following scheme, based on the life-history, wings, and mouth-parts, is widely employed and will serve for all practical purposes. It recognizes nine distinct orders, arranged in three groups.

A. AMETABOLA

Order 1.—**Aptera.** Primitive Wingless Insects. Small forms, feebly mandibulate. Exs.: Tassel-tails and spring-tails.

B. HEMIMETABOLA

Order 2.—**Orthoptera.** Straight-winged Insects. Four wings; front ones horny wing-cases that overlap when closed; hind ones folded up like a fan when not in use. Mandibulate. Exs.: Cockroaches, grasshoppers, locusts, crickets.

Order 3.—**Neuroptera.** Net-winged Insects. Four similar wings with a close network of veins. Mandibulate. Exs.: Dragon-flies, lace-wing flies, etc.

Order 4.—**Thysanoptera.** Fringe-winged Insects. Minute forms, with four very narrow wings fringed by hairs. Haustellate. Ex.: Thrips.

Order 5.—**Hemiptera.** Bugs. Four wings; front ones membranous or horny except at tip. Haustellate, with piercing and sucking mouth-parts. Exs.: Plant Bugs, bed bugs (wingless), plant lice or aphides (some stages wingless).

C. HOLOMETABOLA

Order 6.—**Coleoptera.** Beetles. Four wings; front ones curved horny wing-cases (elytra) meeting in a straight line down the middle of the back when folded; hind ones long, folded transversely as well as longitudinally when not in use. Mandibulate. Larva a plump grub or else narrow and worm-shaped (wire-worm). Exs.: Cockchafer, lady-bird, beetles chick beetles.

Order 7.—**Hymenoptera.** Membrane-winged Insects. Four membranous wings with few veins. Mandibulate, or mouth-parts adapted for both biting and sucking. Larva either resembling a caterpillar, or helpless, soft, and worm-like. Exs.: Saw-flies, bees, wasps, ants (some stages wingless).

Order 8.—**Lepidoptera.** Scale-winged Insects. Four wings, covered with minute coloured scales. Larva a caterpillar, mandibulate. Adult haustellate, Exs.: Moths.

Order 9.—**Diptera.** Flies. Two membranous fore-wings, with few veins; hind-wings reduced to vestiges. Larva a maggot, mandibulate. Adult haustellate. Exs.; Crane-flies, mosquitoes.

Agricultural etomology is so extensive a subject that it is impossible to do more than deal briefly with a few typical insect foes and friends, and summarize the principles on which preventive and remedial measures depend. Aptera are of little importance and are therefore omitted.

ORDER ORTHOPTERA. STRAIGHT-WINGED INSECTS

The members of this order attack various plants by means of their biting mouth-parts, but only the **earwigs** (*Forficula auricularia* and others) are serious pests in this country, though the **common cockroach** (*Stylopyga orientalis*) is a nuisance in houses and other buildings. But in other parts of the world some of the Locusts occur in enormous swarms and are responsible for wholesale devastation, especially as they may possess marked

powers of migration. They are to be found in both Old and New Worlds, one species (*Pachytylus cinerascens*) being particularly numerous in the former, where it ranges from the Atlantic to China.

ORDER NEUROPTERA. NET-WINGED INSECTS

White ants or **termites** (*Termitidae*) are remarkable for living in complex communities containing several distinct kinds of individual, and are notorious for the way in which they destroy furniture and wooden houses in some of the warmer regions of the globe.

The most conspicuous members of the order in this country are the dragon-flies (*Odonata*), highly carnivorous

FIG. 68. LACE-WING FLY (*Chrysopa vulgaris*)

a, eggs; *b*, larva; *c*, cocoon; *d*, pupa; *e*, open cocoon; *f*, adult; *a*, *c*, *e*, natural size; *d*, natural size and enlarged; *b*, *f*, enlarged.

forms which in the adult stage hawk for other insects on the wing, while their aquatic larvae destroy various small animals. They are perfectly harmless and do not sting as sometimes supposed, and are decidedly beneficial to agriculture since they destroy many pests. The delicate little **lace-wing flies** (*Hemerobiidae*) are still more useful, for their larvae ('aphis lions') possess formidable mandibles and destroy great numbers of aphides (Fig. 68).

The small wingless forms known as **bird-'lice'** (*Mallophaga*) infest some domesticated animals and prevent them from thriving. Species of no less than four distinct genera abound on fowls, gnawing the feathers and skin.

Some domesticated mammals—sheep, ox, horse, dog, and cat—harbour species of another genus (*Trichodectes*), and these cause intolerable itching.

ORDER THYSANOPTERA. FRINGE-WINGED INSECTS

The minute insects (species of *Thrips*, etc.) that are included in this order are popularly known as **black flies,** on account of their dark colour, or as thunder flies. They may occur in very large numbers on various cultivated plants, especially cereals, piercing and sucking the sap of the young shoots and immature grains. They also attack peas, beans, melons, cucumbers, and tomatoes.

ORDER HEMIPTERA. BUGS

Three sub-orders are usually recognized:—(1) Homoptera. The fore-wings, when present, are membranous. (2) Heteroptera. The fore-wings, when present, have membranous tips. (3) Anoplura. Wingless parasites.

(1) **Homoptera.**—Two very important families of pests are here included, the plant-lice or aphides (*Aphididae*), and the scale insects (*Coccidae*).

A great many cultivated plants are attacked by species of **plant-lice,** one of the most familiar being the **bean aphis** (*Aphis rumicis*), also known as collier, black fly, and dolphin (Fig. 69). As in all its kind propagation takes place very rapidly, and many generations are produced in the year. The eggs remain dormant during

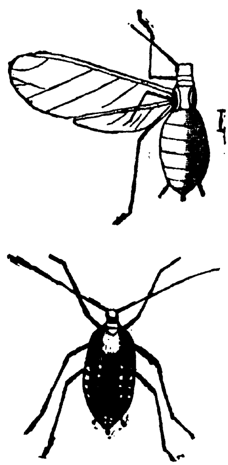


FIG. 69. BEAN APHIS (*Aphis rumicis*)
Winged and wingless individuals. Natural size indicated by line on right of former.

autumn and winter, hatching out in the spring into wingless females, which produce living female young without fertilization, i.e. *parthenogenetically*. These, in their turn, produce another set of wingless females in about twenty days, or it may be less, and the process is continued during the summer until at last a generation of winged females makes its appearance, which is able to spread the infestation. In autumn the winged females produce males and wingless egg-laying females. Docks, thistles, and other weeds also harbour this pest, and provide it with food when beans are not available.

Scale insects (Fig. 70), notorious pests on fruit-trees and bush fruit, derive their name from the fact that the wingless and usually legless female, which remains permanently anchored by her piercing and sucking mouth-parts, is covered and protected by a scale-like shield made up of cast skins and excrement. The small—and at first active—male possesses membranous fore-wings, but the hind ones are reduced to hooks. In this sex the mouth-parts are so reduced that feeding is impossible.

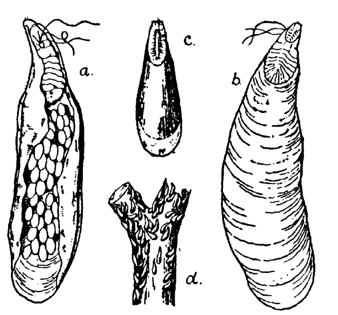


FIG. 70. MUSSEL SCALE INSECT (*Mytilaspis pomordum*)
a, Female, from below; *b*, ditto, from above; *c*, male, from above (all three enlarged); *d*, infected twig (natural size).

Heteroptera.—These are not of great agricultural importance, but the needle-nosed hop-bug (*Calocoris fulvomaculatus*) and **hop frog-fly** (*Euacanthus interruptus*) attack the crop after which they are named. Some species belonging to the sub-order are carnivorous and may be regarded as beneficial.

Anoplura.—Here are included the blood-sucking **lice**, of various species, which are usually included in the

Hemiptera though their actual affinities are doubtful. Different species of the same genus (*Haematopinus*) infest horse, pig, ox, and dog.

ORDER COLEOPTERA. BEETLES

Beetles possess powerful biting mouth-parts in both the larval and adult stages, and many of them are serious pests, while others are beneficial in varying degree.

Turnip flea-beetles (*Haltica nemorum* and *H. concinna*), popularly known as turnip 'flies,' are small forms with well-developed hind-legs by means of which they spring like fleas (Fig. 71). Turnips and other cruciferous crops

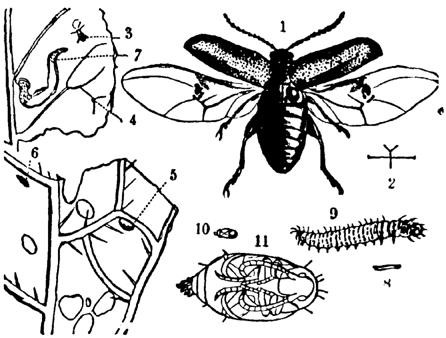


FIG. 71. TURNIP FLEA-BEETLE (*Haltica nemorum*)

1, adult (enlarged), with wing-covers and wings expanded; 2 and 3, natural size of same; 4 and 5, egg (natural size and enlarged); 6, 7, burrows of larvae; 8, 9, larva (natural size and enlarged); 10, 11, pupa (natural size and enlarged).

suffer greatly from their ravages, especially when in the seedling stage, and they also attack cruciferous weeds. During the winter the last developed batch of adults hibernate in all sorts of sheltered places, emerging in spring to destroy seedlings by biting through the stem just below the cotyledons. The eggs are laid on the under sides of the leaves of older plants, and the voracious larvae tunnel in the soft leaf substance, falling to the ground when fully fed to become pupae just below the surface of the

soil. There are many successive generations during the year.

Click-beetles or **skip-jacks** (*Agriotes lineatus* and *Athous haemorrhoidalis*) are somewhat larger species (Fig. 72), which possess a curious springing apparatus on the under side of the body, by means of which they can propel themselves into the air with a clicking sound. The larvae, known as **wireworms**, live underground, taking from three to five years to mature, and do much damage by gnawing the roots and subterranean stems of nearly all crops except mustard. They are particularly abundant in grass land, especially permanent pasture.

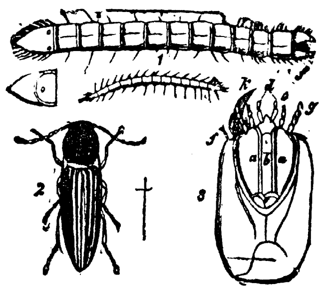


FIG. 72. CLICK BEETLE (*Agriotes lineatus*)

1, Larva, natural size (below) and enlarged (above), tip of abdomen to left; 2, adult (enlarged), natural size indicated on right; 3, under side of head of larva (enlarged). *a*, Maxilla; *b*, under lip; *d*, labial palps; *e*, *g*, inner and outer maxillary palps; *f*, antennae; *k*, mandible.

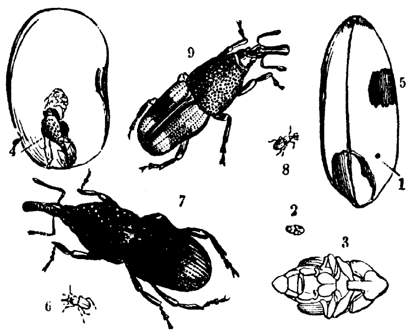


FIG. 73. WEEVILS

1, Grain of wheat, showing small hole of entry and, above this, exit hole (5); 2, 3 pupa (natural size and enlarged); 4, grain of maize, with weevil inside; 6, 7, corn weevil (*Calandra granaria*), natural size and enlarged; 8, 9, rice weevil (*C. oryzæ*) natural size and enlarged.

The small beetles known as **weevils** are very destructive pests. In these forms the head is prolonged into a narrow snout bearing the antennae, and the larvae are legless grubs (Fig. 73). Common examples are :—**apple-blossom w.** (*Anthonomus pomorum*) which lays its eggs in the flower-buds ; **pea** and **bean w.** (*Sitones lineatus* and *S. crinitus*), which devour the leaves, while the larvae attack the roots ; **bean-seed w.** (species of *Bruchus*), which lay

FIG. 74.—SEVEN-SPOTTED LADY-BIRD BEETLE (*Coccinella septempunctata*) Larvae, pupae, and adults ; all natural size.

their eggs in immature beans, within which the development takes place ; and **grain w.** (species of *Calandra*), that behave in the same way as regards cereals.

Fortunately there are some beneficial species in the order, and the most important of these are the familiar little **lady-bird beetles** (*Coccinellidae*), which both as larvae and adults wage effective war against aphides and scale insects (Fig. 74).

ORDER HYMENOPTERA. MEMBRANE-WINGED INSECTS

The most serious pests belonging to this order are the **saw-flies** (*Tenthredinidae*), so called because the female possesses an ovipositor with saw-like blades. These are used for making incisions in leaves or young stems, within which the eggs are deposited. The voracious mandibulate larvae resemble the caterpillars of moths and butterflies, but differ from these in certain details and are conveniently distinguished as 'false' caterpillars (Fig. 75). In addition to three pairs of jointed legs behind the head, corresponding to the thoracic limbs of the adult, both types of

larva possess a varying number of unjointed pro-legs ending in suckers, one pair of these—the anal pro-legs—being at the posterior end of the body. In addition to these last, a false caterpillar is provided with more than four pairs of central pro-legs, while four is the maximum for a caterpillar. False caterpillars can also be recognized by their heads being rounded instead of flattened, by the way they 'rear up' when disturbed, and the habit of curling the posterior end of the body into a spiral curve when in a state of rest. Pupation takes place in the ground. Particularly notorious species are the **gooseberry** and **currant saw-fly** (*Nematus ribesii*), and the **turnip saw-fly** (*Atharia spinarum*) (Fig. 76).

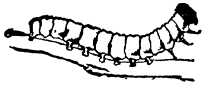


FIG. 75. FALSE CATERPILLAR

In many Hymenoptera the female possesses a sting at the tip of the abdomen, and this is provided with a poison-gland. The larvae of such forms are devoid of legs and more or less helpless. **Ants** and ordinary wasps, which are

FIG. 76. TURNIP SAW-FLY (*Athalia spinarum*)
Adult female and two larvae. Scale indicated to right of former.

associated in complex communities, are examples of pests belonging to the stinging species.

Fortunately a great many Hymenoptera are beneficial. Conspicuous among these are the inconspicuous **ichneumon-flies** (*Ichneumonidae*), over 1,200 species of these being British. The female possesses a long ovipositor, and the eggs are deposited on or in the larvae of a great variety of insects, many of these being pest-forms such as caterpillars, which are gradually devoured by the parasitic ichneumon larvae that hatch out, but which avoid the vital organs of their hosts (Fig. 77).

Some of the stinging Hymenoptera are also beneficial, such as the **solitary wasps** (Fig. 78) some of which store up caterpillars as a kind of living larder for their helpless young, previously paralysing these victims by stinging them in the ventral nerve-cord.

Here too must be mentioned our only domesticated

FIG. 77. ICHNEUMON FLY (*Microgaster glomeratus*), which attacks caterpillars of large Cabbage—White (*Pieris brassicæ*)

Left, adult; right, larva (natural size indicated by lines). In the middle, a dead caterpillar with heap of ichneumon-fly cocoons.

insect, the **honey-bee** (*Apis mellifica*), fully dealt with in such a standard work as Cowan's *British Bee-keeper's Guide-book.* It is familiar knowledge that the large community making up the population of a hive consists of a fertile female (queen), sterile females (workers), and males

FIG. 78. SAND-WASP (*Ammophila sabulosa*). Natural size.

(drones). It is also important to remember that the honey-bee renders invaluable services by pollinating flowers, and for this reason a small apiary should form part of the equipment of the specialist fruit-grower.

ORDER LEPIDOPTERA. SCALE-WINGED INSECTS

This extensive order includes a vast number of butterflies and moths, which in the adult stage are useful agents of pollination, though this good work is largely counter-

balanced, in many cases, by the extreme voracity of their caterpillars. The first maxillae of the adults are drawn out into a long proboscis, which is spirally coiled when not in use (Fig. 79). The flat-headed mandibulate **caterpillar** is provided with not more than four pairs of central pro-legs in addition to the anal ones (cp. p. 200). Sometimes the former are reduced to one or two pairs, as in the looper or geometer caterpillars, so named on account of their curious mode of progression (Fig. 80).

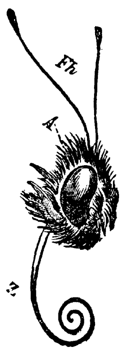


FIG. 79. HEAD OF BUTTERFLY
A, Compound eye; *Fh*, antennae; *Z*, proboscis.

The **pupa** or **chrysalis** may be devoid of investment, or else protected within a silken cocoon or covering of earth. Pupation takes place in various places, not infrequently in the ground.

The comparatively few British **butterflies** are easily distinguished from the innumerable moths by their club-shaped antennae, and the fact that their wings are folded together over their backs when they settle, so that the conspicuously coloured upper sides are concealed, as a protective measure. Of our native species only the **Whites** (*Pieridae*) are of any great importance. They include the **large** or **cabbage white** (*Pieris brassicae*) (Fig. 81), the **small white** (*P. rapae*), and the **green-veined white.** (*P. napi*). The caterpillars of all three infest cruciferous crops.

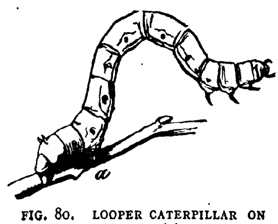


FIG. 80. LOOPER CATERPILLAR ON TWIG (*a*)

A great many **moths** are pests, among the most familiar being species of which the larvae are known as **surface caterpillars** or **cut-worms.** These are dull in colour, and attack a great variety of field and garden crops. Most of them belong to one or other of three species of **moth:**

the **dart** or **turnip moth** (*Agrotis segetum*) (Fig. 82), the **heart-and-dart moth** (*A. exclamationis*), and the **yellow**

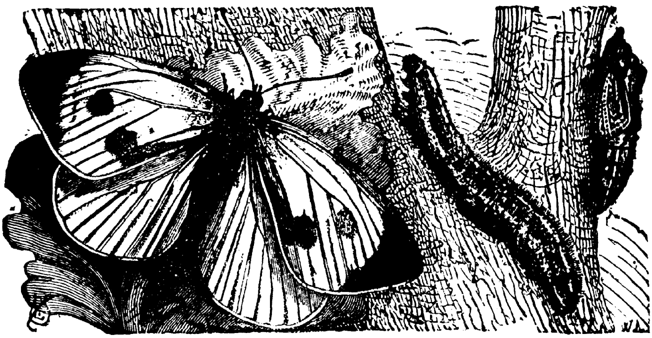


FIG. 81. CABBAGE-WHITE BUTTERFLY (*Pieris brassicæ*)
Female laying eggs; caterpillar; and pupa.

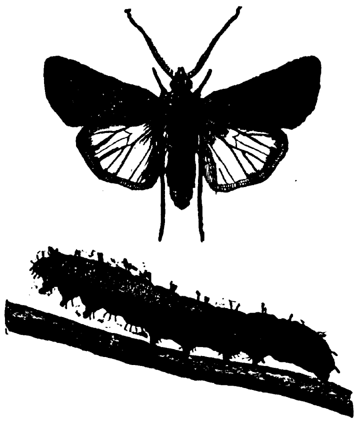


FIG. 82. TURNIP MOTH (*Agrotis segetum*), WITH CATERPILLAR

under-wing (*Triphaena pronuba*). They pass through the pupa stage in the ground, enclosed in cells of compacted earth.

ORDER DIPTERA. FLIES AND FLEAS

The members of this order have mouth-parts adapted for piercing and sucking, or for the latter only. Most of them possess membranous fore-wings with few veins, while the hind-wings are reduced to vestiges, which in many cases are short knobs known as **balancers** (halteres) that have sensory functions. Fleas and some flies are entirely devoid of wings. The larva is a footless **maggot** with biting mouth-parts, and in some cases it and the pupa stage are aquatic.

This enormous order includes over 40,000 known species: 'but these are only a tithe of what are still unknown to science.' (David Sharp). Many are crop-pests, while still more are injurious to stock or to human beings.

The following are a few species of which the larvae are **injurious to crops: Hessian-fly** (*Cecidomyia destructor*), harmful to wheat, barley, rye, and some grasses; **wheat midge** (*Diplosis tritici*) attacking the flowers of wheat; **onion-fly** (*Phorbia cepetorum*), devouring the bulb; **cabbage-root flies** (species of *Anthomyia*), feeding on the roots and lower parts of the stems of cabbages and turnips; **mangel-fly** (*Chortophila betae*), tunnelling the leaves of beet and mangel; **gout-fly** or **ribbon-footed corn-fly** (*Chlorops taeniopus*), from the attacks of which barley fails to develop grain and becomes stunted and swollen; **frit-fly** (*Oscinis frit*), destroying the shoots of oats; **carrot-fly** (*Psila rosae*), causing 'rust'; and **celery-fly** (*Tephritis onopordinis*), blistering the leaves of celery and parsnip.

The **crane-flies** or **daddy-long-legs** (species of *Tipula*) are larger and therefore more familiar than any of the foregoing, and their tough-skinned larvae, familiarly known as 'leather jackets,' gnaw the underground parts of almost all crops, being particularly obnoxious in damp permanent pasture (Fig. 83). There are two broods in the year, and the second set of larvae live through the winter.

Forms injurious to stock or human beings.—The **breeze-flies** or **horse-flies** (*Tabanidae*), notorious blood-suckers,

include the **gad-flies** (species of *Tabanus*), the sluggish **clegg** or 'old maid' (*Haematopota pluvialis*), and the **golden-eyed fly** (*Chrysops caecutiens*). All these worry horses and cattle, and also attack human beings.

FIG. 83. CRANE-FLY (*Tipula oleracea*)
Left, male and larva; right, female and pupa.

The **bot-flies** (*Oestridae*) do not bite or suck blood as adults, but their larvae ('bots') cause much mischief as internal parasites in some of the domestic animals. The female of the **horse bot-fly** (*Gastrophilus equi*) lays her eggs on

FIG. 84. HORSE BOT-FLY (*Gastrophilus equi*)
a, Egg on hair (much enlarged); *b*, young larva (enlarged); *c*, older larva; *d*, opened pupa-case; *e*, adult.

the hairs of the fore-limbs of the horse (Fig. 84). They are licked off, hatch out in the mouth, and crawl down the gullet into the stomach, attaching themselves to the mucous membrane by means of their strong jaws. In this position the

larvae may remain for almost a year, and are about an inch long when fully grown. The mature bots are barrel-shaped, and provided with circlets of spines. At the end of the larval stage they loose their hold and pass to the exterior in the dung to pupate in the ground.

The eggs of the **ox bot-fly** or **warble-fly** (*Hypoderma bovis* and *H. lineata*) are laid on the legs and flanks of cattle, boring into the skin when hatched out. They travel into the wall of the gullet, and thence to the back, where they live under the skin and cause swellings ('warbles') that are perforated to admit air. When full grown the bots make their way to the exterior, fall to the ground, and become pupae. Infested cattle fall off in condition, the hide loses its value for tanning purposes, and parts of the superficial muscles become jelly-like ('licked beef').

The larvae of the **sheep bot-fly** (*Oestrus ovis*) live in the nasal cavities of sheep for the better part of a year, and then wriggle or get sneezed out to pupate in the ground.

Some of the **gnats** or **mosquitoes** (*Culicidae*) are responsible for serious diseases of human beings, for the blood-sucking females introduce parasitic Protozoa into the circulation of their victims. Malarial complaints, for example, are spread by species of *Anopheles*, and yellow fever by *Stegomyia fasciata*. Other examples of diseases disseminated by blood-sucking Diptera will be given elsewhere.

The slow-flying **forest** or **horse-fly** (*Hyppobosca equina*) irritates horses and cattle, and sucks their blood, in some parts of this country, and the wingless **ked** or **sheep 'tick'** (*Melophagus ovinus*) is a related species.

Few pests are more objectionable than the cosmopolitan **house-fly** (*Musca domestica*), for though this does not bite it spreads many disease bacteria, especially those causing typhoid fever, cholera, tuberculosis, and summer diarrhoea of infants, more particularly by introducing these into milk. The importance of 'clean' milk can hardly be overestimated, and infantile mortality could be greatly reduced by employing the sterilized or pasteurized product, or by

the use of reconstituted milk made as required from milk powder. The **sheep-maggot-fly** (*Lucilia sericata*) belongs to the same family.

Fleas are wingless blood-sucking parasites generally included in the Diptera. The common flea (*Pulex irritans*) is the ordinary house-pest, but other kinds infest dogs, cats, poultry, rats and mice. Some of the rat-fleas (especially *Xenopsylla cheopis*) spread the germs of bubonic plague.

A few flies are **beneficial**. The larvae of caterpillar flies (*Tachinidae*), for example, are parasitic in the larvae of moths and butterflies; while the **hover-flies** (*Syrphidae*) are important as pollinating agents.

THE COMBATING OF INSECT PESTS

All animals increase rapidly in number up to a point determined by conditions of various kinds, one such condition being the amount of food available. Man upsets the balance of nature by growing crops and keeping stock, and these afford a large amount of food for many insect pests, enabling them to increase unduly until a limit is imposed by some kind of natural or artificial check. It is therefore necessary to adopt preventive measures where possible, and to supplement these by remedial measures. Success in both directions depends on accurate knowledge, and this is being continually increased by scientific research.

Preventive Measures.—Much can be done by good farming, for this means healthy crops and stock, which are less liable to attack than those which are weak or sickly. It is also recognized that crops are most susceptible to various forms of insect attack in the early stage of life when they are delicate seedlings, and it is desirable therefore to promote their rapid growth so as to hurry over this stage. The young seedlings of turnip for instance are easily destroyed by the turnip-fly (p. 197), and have a much better chance of survival in later stages of growth.

Suitable **rotation of crops** is a preventive measure of great importance, especially in the case of pests that limit

their attentions to one or few kinds of plant. Continuous cropping, on the other hand, is obviously favourable to such pests. **Suppression of weeds** is also of considerable value, for many of these harbour injurious insects as well as fungoid pests. Charlock (*Sinapis arvensis*) and other wild crucifers, for example, are infested by the turnip-fly, and keep it going until the turnip-seeds begin to sprout. The same is true for docks and several other weeds in regard to the bean aphis (*Aphis rumicis*).

Certain insects, such as weevils, attack seeds and grain, and in such cases the employment of **clean seed** is a common-sense precaution, as otherwise the pest is sown with the crop, so to speak.

The protection and encouragement of beneficial insectivorous animals may do much to prevent the undue increase of insect pests. This applies more particularly to moles, bats, and birds, and we here see the importance of accurate investigation, in order that we may know our friends from our foes. The encouragement of beneficial insects, such as lady-bird beetles and ichneumon flies, is theoretically even more desirable, but the incompleteness of our knowledge has so far prevented the adoption of any practical measures in that direction, though importation of the former has been tried with success for suppressing certain scale insects. All we can do, as a rule, is to refrain from killing insects known to be useful. If, for example, large numbers of lady-bird beetles make their appearance on a bean field we can feel quite sure that they are after aphides and not attacking the crop.

Remedial Measures.—Most pests could be dealt with efficiently by one or more methods were it not for considerations of cost. Only cheap insecticides can be employed in most cases, and the labour bill must be reasonable. The very extensive literature of the subject should be consulted for details, and only a few general remarks are possible here.

Hand picking of caterpillars and other larvae is effective, but the cost of labour rules this out except in the case of

some of the more valuable crops. Many methods of attack depend on knowledge of life-histories, and advantage is taken of the fact that in many cases pests spend part of their lives on or in the ground. The **gooseberry** and **currant saw-fly** (p. 200), for instance, pupates in the ground, and can be destroyed by application of gas-lime, or by removing and burning about two inches of the soil during the winter. The pupae of the winter moth (*Cheimatobia brumata*), is a well-known fruit-tree pest, are also to be found in the ground, and the females are incapable of flight owing to the great reduction in size of their wings (Fig. 85). **Grease-banding** the trunks consequently prevents them from crawling up to lay their eggs in the shoots.

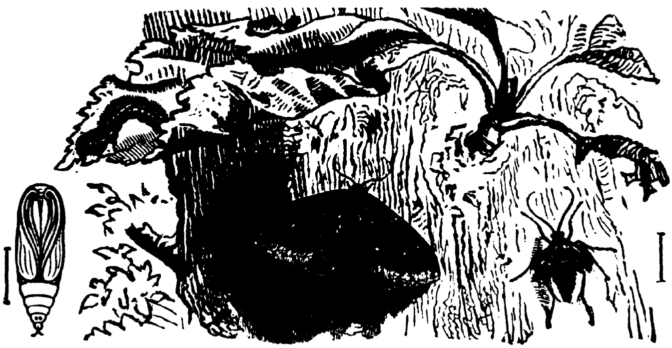


FIG. 85. WINTER MOTH (*Cheimatobia brumata*)
Female on right; male in centre; caterpillar and chrysalis to left (actual size of first and last indicated by lines).

Insecticides are broadly divided into two classes, those employed for killing mandibulate insects, and those used for destroying haustellate forms. In the former case the aim is to poison the food of the pest, as by application of arsenical preparations such as Paris green. Haustellate forms, such as aphides, need direct treatment with substances that destroy them by contact or block up their breathing pores so as to cause suffocation. Petroleum emulsions are largely employed for these purposes.

Insecticides are applied either in the form of fine sprays

or finely divided powders, but the best results can only be obtained by experts, for many things have to be considered, among these being the kind of pest; the composition and strength of the preparation; the amount necessary; and the time and method of its application.

CLASS ARACHNIDA

The most familiar forms included in this class are Scorpions, Spiders, and Mites. The **head** and **thorax** are always fused together, while the **abdomen** may either be clearly marked off from the latter, as in a spider, or closely united with it, as in a mite. There are no antennae, but the head bears two pairs of appendages, the **chelicerae** and **pedipalps**, that serve as jaws. Four pairs of **legs** are attached to the thorax. Except in the aquatic King-Crabs, which breathe by gills and require no mention here, organs of respiration are **air-tubes**, as in insects, or pouch-like '**lung-books**' into which project numerous thin plates full of blood spaces. Development may be direct, or there may be a more or less considerable metamorphosis.

Spiders are beneficial animals, as they destroy a large number of noxious insects, but **Mites** are of much greater importance, and many are serious pests. Large mites are known as **Ticks**. These forms are parasitic in habit, usually possessing mouth-parts adapted for piercing and sucking: they either breathe by air-tubes or are devoid of respiratory organs: and the life-history includes a number of different stages.

Some plants are attacked by mites, such as the **spinning mites** or **red 'spiders'** (species of *Tetranychus*), which infest bush-fruit and hops; and gall-mites, of which one species (*Eriophyes ribis*) causes 'big bud' in black currant.

Ticks suck the blood of stock, and in doing so some of them introduce protozoan parasites causing a number of diseases, such as red water in cattle, and louping-ill in sheep. Different kinds of mange are due to **mites**, and of these three distinct sorts are recognized: (1) Those which

live on the skin and devour epidermic scales, particularly on the fetlocks of the horse and near the root of the tail in cattle. (Species of *Dermatophagus.*) (2) Blood-sucking forms infesting the horse (inner sides of the legs; genital organs; and tail), and ox (sides of the neck and root of the tail). (Species of *Dermatocoptes.*) (3) Burrowing forms (species of *Sarcoptes*) (Fig. 86), setting up itch or scabies in domesticated mammals and man, and responsible for scaly leg and feather-eating in poultry. Sheep scab is also due to a burrowing mite (*Psoroptes communis*), while the **red hen-mite** (*Dermanyssus avium*), a surface blood-sucker, is a great nuisance in the poultry yard.

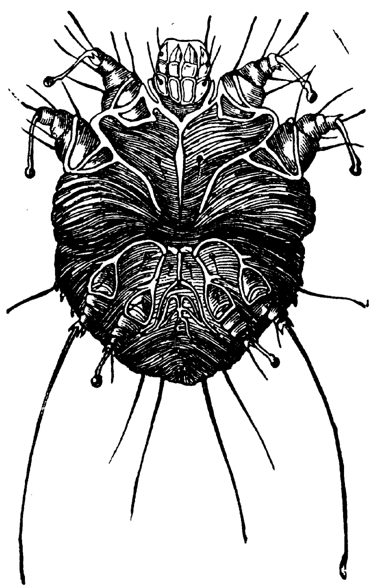


FIG. 86. MANGE-MITE (*Sarcoptes scabiei*) FROM UNDER-SIDE (enlarged)

PHYLUM **ANNELIDA.** SEGMENTED WORMS

This phylum includes innumerable marine forms; certain fresh-water species; earthworms; and leeches. We are only concerned here with **earthworms**, of which there are many British species (mostly belonging to the genera *Lumbricus* and *Allolobophora*). The cylindrical body is made up of a large number of segments, and is devoid of limbs, but possesses four double longitudinal rows of minute bristles that protrude from pouches in the skin and aid locomotion. The alimentary canal is a straight tube,

divided into several regions, one of which is a muscular gizzard, which grinds up the food, aided by small stones that are swallowed, much as in a bird. This makes up for the absence of jaws or teeth. The sexes are united, but self-fertilization does not take place. The fertilized ova develop in small horny cases or cocoons, which are deposited near the surface of the ground.

Earthworms are for the most part beneficial to agriculture and horticulture. Their staple food consists of earth, and they literally eat their way through the ground, thus forming burrows that facilitate drainage. The earth that has passed through their bodies is deposited on the surface in 'castings' composed of very finely divided material. It can therefore be said that earthworms assist in the formation of tilth, and as they bring material from below, are continually mixing up the soil, causing each part in turn to be exposed to the surface agents of disintegration. It has been calculated that an acre of ordinary farm land may contain as many as 50,000 worms, and Darwin estimated that about ten tons of earth per acre passes through the bodies of these animals annually.

Phylum **NEMATHELMIA.** Round Worms

This phylum includes a host of cylindrical unsegmented worms, of separate sexes, and mostly parasitic, some attacking plants and a still larger number infesting stock. Most of them are of small size, and many are minute or even microscopic.

Crop Parasites.—These include a good many of the minute eel-worms (*Anguillulidae*). The **wheat eel-worm** (*Tylenchus scandens*) causes the disease variously known as purples, ear cockle, and peppercorns, where the grains are more or less replaced by purplish galls containing great numbers of larvae (Fig. 87). A related species, the **stem eel-worm** (*T. devastatrix*) attacks the shoots of oats (' tulip root '), rye, buckwheat, clover, and potato, checking

growth in length and causing thickening at the base. One kind of 'clover sickness' is attributed to its presence.

The **beet eel-worm** (*Heterodera schachtii*) brings about swelling and decay of the root, and is responsible for 'beet sickness' of the soil. The allied **root-knot eel-worm** (*H. radicicola*) infests the roots of many plants, particularly clover, lucerne, cucumber, and tomato.

STOCK PARASITES.—Domesticated animals, and man himself, are infested by many of these pests. No less than twenty distinct species are known to occur in the horse alone. The following are some of the more important forms.

Palisade Worms or **Strongyles** (*Strongylidae*).—**Lung-worms** of several kinds infest the respiratory organs of sheep, one of the most objectionable (*Eustrongylus filaria*) causing 'husk' or 'hoose' in lambs. Various Armed Strongyles are parasitic in the horse. Of these the **giant strongyle** (*Sclerostomum gigas*), of which the female is nearly a foot long, lives in the kidneys; another species (*S. armatum*) bores from the large intestine into some of the blood-vessels: and two others (*S. tetracanthum* and *S. rubrum*), even more injurious, cause swellings in the wall of the large intestine, and set up inflammation, colic, and other disorders.

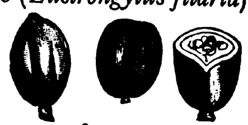


FIG. 87. EAR-COCKLES OF WHEAT

Larvae of Wheat Eelworm (*Tylenchus scandens*) seen on cut surface of one to right.

The **Gape-worm** (*Syngamus trachealis*), infesting the air-tubes of poultry and some other birds, also belongs to this family.

Whip-worms (*Trichocephalidae*).—This family is named after the type genus (*Trichocephalus*), in which the front part of the body is very slender, and is imbedded in the mucous membrane lining the intestine of the host, this being most commonly the sheep or pig. A much smaller but serious pest included in the same family is **Trichina** (*T. spiralis*) which causes the disease known as *trichinosis*, common to rat, pig, and man. The young worms are found

encysted in the muscles, and develop no further, unless they are transferred to the stomach of another host (Fig. 88). If, for instance, a human being eats trichinosed pork that has been imperfectly cooked or, as in the case of the raw ham esteemed by Germans, not cooked at all, the worms are liberated from their cysts by the action of the gastric juice. They then rapidly become sexually mature and breed in the stomach, their offspring boring their way into blood-vessels to reach and be encysted in the muscles. Pigs contract the disease by devouring infected rats.

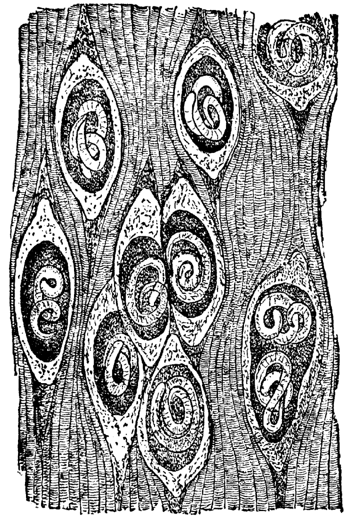


FIG. 88. ENCYSTED TRICHINAE (*Trichina spiralis*) IN PORK (enlarged)

Round-worms proper (*Ascaridae*) include the largest members of the phylum, the biggest being the **horse-worm** (*Ascaris megalocephala*), common in the intestines of the horse and its immediate allies. The female may be ten inches long, and the male six. A smaller species (*A. suilla*) infests the small intestine of the pig.

The **Slender Thread-worms** (*Filariidae*) are elongated parasites, found in various parts of the body, but not in the digestive tube. One of the commonest species (*Filaria papillosa*) may occur in large numbers in the thoracic and abdominal cavities of the horse.

Phylum **PLATYHELMIA.** Flat Worms

These are unsegmented flattened animals, including two important classes of hermaphrodite parasites, Trematoda (Flukes), and Cestoda (Tape-worms), of which some species infest domesticated animals and also man.

Trematoda. Flukes.—The **liver fluke** (*Distomum hepaticum*) is only too well known as the cause of liver 'rot' in sheep. The leaf-shaped body is about an inch in length, with the mouth in the centre of a small sucker placed at the end of a small anterior projection (Fig. 89). There is a second sucker a little way behind this on the ventral surface. The skin is studded with minute spines that help the parasite to wriggle its way along the branches of the bile duct and through the disintegrating liver tissue which, together with blood, constitutes its food. There are complicated male and female reproductive organs, and the eggs, enclosed in firm investments, pass down the bile duct into the intestine and ultimately to the exterior in the dung.

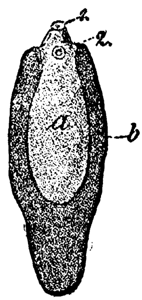
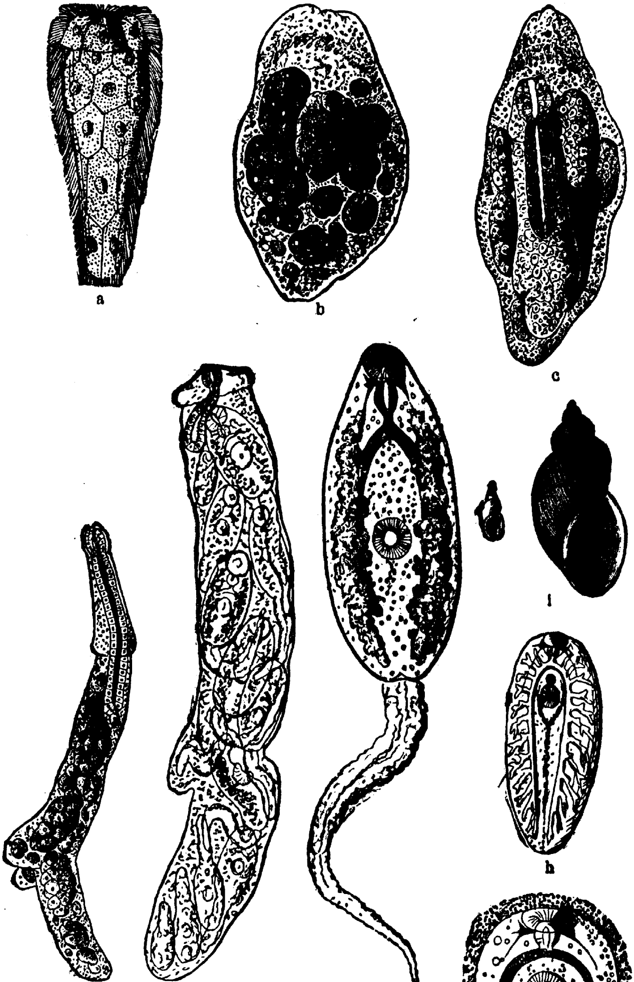


FIG. 89. LIVER FLUKE (*Distoma hepaticum*) natural size

1, Front sucker; 2, ventral sucker; *a*, *b*, clear and opaque regions of body.

Should an egg fall into a puddle it hatches out after a time into a **ciliated larva,** which swims actively about (Fig. 90). Further development is only possible if, within thirty hours, it meets a small water-snail (*Limnaeus truncatulus*) which serves as a first or **intermediate host.** For, like many other parasites, its life-history is spent in more than one kind of organism, the name **final host** being given to that in which the adult sexual stage is reached, in this case the sheep. If the ciliated embryo succeeds in finding a snail it becomes parasitic in this, and is transformed into a shapeless **sporocyst,** which produces by a sort of internal budding a number of the next stage—**redia**—in the life-history. A varying number of generations of daughter rediae are developed in a similar way, and the last



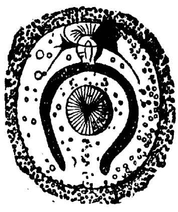


FIG. 90. LIVER FLUKE

a, free swimming ciliated larva ; *b*, young *sporocyst*, a few days after migration into the snail ; *c*, *sporocyst*, containing rediae in various stages of development ; *d*, *redia*, containing balls of germinal cells ; *e*, mature *redia*, containing its brood of cercariae ; *f*, mature cercaria ; *g*, just-encysted *cercaria* ; *h*, young fluke, soon after entering sheep ; *i*, the water snail, *Limnaeus truncatulus*. *a*, *b*, *c*, *d* × 200 ; *e* × 150 ; *f* × 300 ; *g* × 150 ; *h* × 25 ; *i*, natural size and × 2

of these give rise to a brood of the succeeding stage—**cercaria**—somewhat resembling a minute tadpole in appearance. The cercaria makes its way out of the snail, swims to a grass-stem or something similar, loses its tail, and becomes encysted. If now swallowed by a sheep the protective covering is dissolved by the gastric juice, thus liberating the young fluke, which passes into the small intestine and makes its way up the bile-duct into the liver, there to become sexually mature.

From what has been said it is clear that a diseased sheep cannot infect others, and that the obvious way to deal with the pest is to exterminate the snail, by thorough drainage of land and otherwise.

Spraying with copper sulphate has recently been tried with good results as a remedial measure.

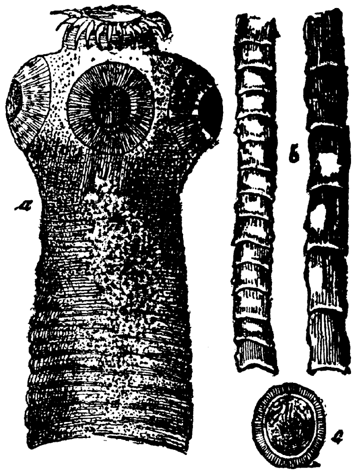


FIG. 91. COMMON TAPE-WORM (*Taenia solium*)
a, Head and neck (much enlarged); *b*, joints (natural size); *c*, six-hooked larva enclosed in egg-shell (much enlarged).

Cestoda. Tape-worms.—These are hermaphrodite band-shaped internal parasites devoid of digestive organs and, with a more or less complex life. History usually passed throug in two different kinds of host.

The **common tape-worm** (*Taenia solium*) furnishes a well-known example. Here the 'worm' or sexual adult which lives in the intestine of man (final host) consists of a minute head (scolex) and a long series of joints (proglottides), each possessing a double set of reproductive organs (Fig. 91), By means of four suckers and a circlet of hooks the head clings to the mucous membrane, and new joints

are continually formed at its posterior end by transverse constriction. As we pass away from the head the joints become more and more mature, and those at the posterior end are full of embryos enclosed in calcareous shells. From time to time such ripe joints become detached and pass out to the exterior.

Should a ripe joint be swallowed by a pig (intermediate host) the solvent action of the gastric juice liberates the minute embryos, each of which is a fluid-filled sphere possessed of six hooks by which it bores into the wall of the stomach, enters a blood-vessel and gets carried to one of the muscles (Fig. 92). Here encystment takes place and a tape-worm head is developed as an internal projection from the wall of the sphere. Growth is then arrested, the 'bladder worm' or 'cyst stage' as it is now called remaining dormant until the death of the host (Fig. 93).

FIG. 92. TAPE-WORM LARVA (of *Taenia solium*) Much enlarged.

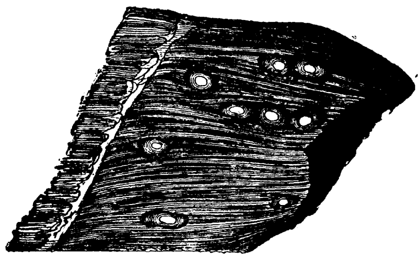


FIG. 93. MEASLY PORK

(natural size), with encysted bladder-worms (*Cysticercus cellulosae*) of common tape-worm (*Taenia solium*). The white spot in each bladder-worm indicates developing tape-worm head.

Should infected or 'measly' pork, insufficiently cooked, be eaten by a human being the bladder-worm develops into an adult tape-worm.

A simple cyst, with only one head, as in the above case, is known as a *Cysticercus*, this particular one being *C. cellulosae*. Before the life-history was worked out the adult tape-worm and the corresponding bladder-worm were

supposed to be distinct species, and a double scientific name was given to each. It was afterwards discovered that the two were merely different stages of the same kind of animal, but we still retain the old name for the cyst, although this might very well have been dropped. The following table summarizes the chief facts regarding some other common tape-worms. It should be noticed that the name *Coenurus* is given to a larger and more complex kind of bladder-worm which possesses a number of heads; while the term *Echinoccus* is applied to a very large kind of cyst into which project a number of daughter-cysts, each with numerous heads. It will also be noticed that in some cases the first name of the bladder-worm stage is used as the second name of the adult.

Name	Bladder-worm and Intermediate Host	Final Host
Taenia mediocanellata (saginata). No hooks. Very numerous joints.	*Cysticercus bovis*. Ox.	Man (small intestine).
T. serrata. 38 to 48 hooks of two sizes. Numerous joints with projecting posterior angles.	*C. pisiformis*. Rabbit (liver and mesentery).	Dog (small intine).
T. marginata. Numerous joints, length twice breadth.	*C. tenuicollis*. Ungulates (mesentery).	Dog (small intestine).
T. coenurus. 24 to 32 small hooks. Many joints.	*Coenurus cerebralis*. Large cyst with several heads. Sheep (brain, causing staggers, gid, or sturdy).	Sheep-dog (small intestine).
T. echinococcus. Minute. Many very small hooks. Only 3 or 4 joints.	*Echinococcus veterinorum*. Very large complex cyst. Man and domesticated Ungulates (liver and various other organs).	Dog (small intestine).

Phylum PROTOZOA. Animalcules

This extremely large phylum includes the simplest forms of animal life, most of which are microscopic. The body is unicellular, but the single cell of which it consists may be greatly specialized. Many species are parasitic, and some of these are responsible for diseases of serious nature. In such cases the life-history is often complicated.

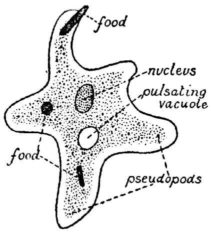


FIG. 94. AMOEBA (much enlarged)

Four groups of Protozoa are of agricultural interest:—(1) Rhizopoda; (2) Flagellata; (3) Ciliata; (4) Sporozoa.

Rhizopoda.—The type of this group is the **proteus animalcule** (*Amoeba*) which resembles a colourless corpuscle in structure (p. 53), and consists of a semi-fluid particle of protoplasm containing a nucleus; but it differs from such a corpuscle in possessing a pulsating vacuole, or liquid-filled space that increases to a certain size, and then suddenly disappears by contraction of the protoplasm that bounds it (Fig. 94). Creeping movements are performed by the protrusion of blunt lobes (pseudopods), and the animal feeds on microscopic plants by simply flowing round them. Creatures of this kind are found in the soil, and destroy many beneficial bacteria (p. 108). Other species, parasitic in the human intestine in some of the hotter parts of the world, cause certain kinds of dysentery.

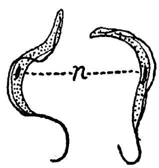


FIG. 95. TRYPANOSOMES (much enlarged) *n*, nucleus.

Flagellata.—These are extremely small Protozoa of definite shape, and provided with locomotor organs in the form of flagella, or whip-like protoplasmic threads, of which one, two, or a small number are present. Some of the flagellates swarm in the soil and prey upon bacteria, while others

are parasitic in various animals, causing serious diseases. The latter belong to the genus *Trypanosoma*, named after a peculiar 'trypanosome' stage in the life-history that infests the red corpuscles of the blood (Fig. 95). A few species are given in the following table :—

Name and Disease	Where prevalent	Animals attacked	Infecting agent
Trypanosoma brucei. Nagana or tsetse fly disease.	Tropical Africa.	Horse, cattle, camel, buffalo.	A tsetse fly (*Glossina morsitans*).
T. gambiense. Sleeping sickness.	Tropical Africa.	Man.	A tsetse fly (*G. palpalis*).
T. evansi. Surra.	India, China, Philippines, China, Africa, Australia.	Ruminants, dog.	*Tabanus* and other flies.
T. equiperdum. Dourine or horse syphilis.	Europe, W. and S. Asia, N. Africa, Chile, N. America.	Horse and Ass.	Contagious by coition.
T. equinum. Mal de caderas (paralysis of hind quarters).	S. America.	Horse.	Unknown.

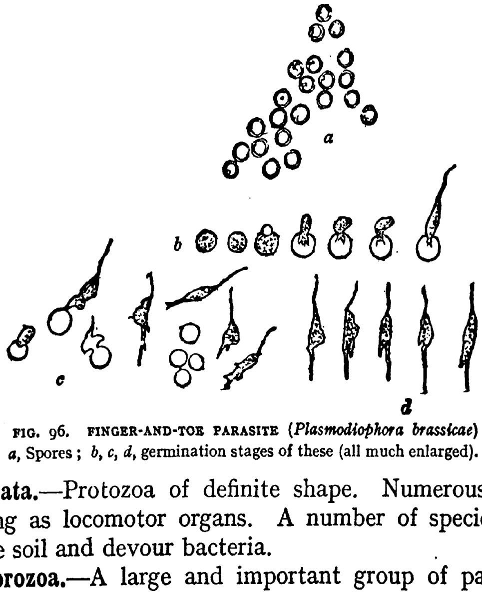


FIG. 96. FINGER-AND-TOE PARASITE (*Plasmodiophora brassicae*)
a, Spores ; *b*, *c*, *d*, germination stages of these (all much enlarged).

Ciliata.—Protozoa of definite shape. Numerous cilia, serving as locomotor organs. A number of species live in the soil and devour bacteria.

Sporozoa.—A large and important group of parasitic forms, with complex life-history. There is an encysted stage, with formation of numerous special reproductive cells or spores.

The organism infesting the roots of turnip and other crucifers (*Plasmodiophora brassicae*), causing club-root, anbury, or finger-and-toe, possibly belongs here, though classified as a fungus by some authorities (Fig. 96). Some blood-diseases occurring in mammals are due to the presence of species belonging to the genus **Babesia**, often known as **Piroplasma**. A pear-shaped form (*B. bigemina*), living within the red corpuscles, generally in pairs, is responsible for the bovine disease variously known as Texas fever, tick fever, and red water (Fig. 97). First discovered in the southern United States, it has since been recorded in S. America, Europe, Africa, India, the Philippines, and Australia. Part of the life-history is passed through in the bodies of ticks (species of *Boophilus*), and these transfer the parasite to cattle when sucking their blood. Malarial diseases, which greatly interfere with tropical agriculture, are due to sporozoan parasites (species of **Plasmodium**) that live in dapple-winged mosquitoes (*Anopheles*) as final hosts, and in the red blood corpuscles of man, the intermediate host. Male mosquitoes are harmless, but the females possess piercing and sucking mouth-parts and, if infected, introduce the parasite into the blood of human beings they attack.

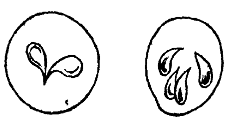


FIG. 97. BABESIA BIGEMINA
Two red corpuscles infested with parasite (much enlarged).

Malarial diseases can only be suppressed by exterminating the mosquitoes that serve as final hosts, and the methods adopted depend on the fact that mosquito larvae are aquatic. They swarm in stagnant water, and since they breathe air are obliged to come to the surface from time to time. Thorough drainage is the most effective measure, because it abolishes the breeding grounds, but where this is not possible the larvae can be killed by pouring a small quantity of paraffin oil on the water in which they live, for this effectually prevents them from reaching the surface to breathe.

Sporozoan parasites belonging to the genus **Eimeria**

(Coccidium) may cause serious disease in certain vertebrate animals. When adult they are ovoid or spherical in shape, and live within the cells of the liver or lining of the intestine of the host (Fig. 98). They are responsible for liver rot in the rabbit, and intestinal complaints in ox, sheep, and poultry.

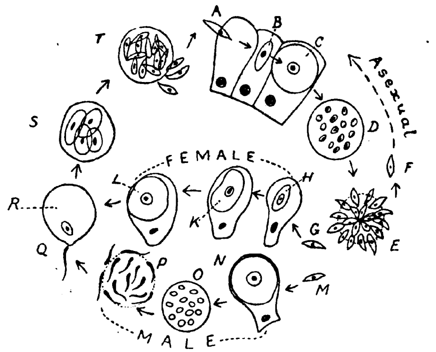


FIG. 98. EIMERIA (*Coccidium*) STIEDÆ
A, B, C, stages of development within three epithelial cells (schizont stage); *D, E*, division of a schizont to form a group of merozoites; *F*, a merozoite about to become parasitic in an epithelial cell, reverting to schizont stage (asexual reproduction); *G, H, K, L*, development of a female cell from a merozoite; *M, N, O, P*, development of a group of motile male cells from a merozoite; *Q*, a male cell fusing with a female cell *R*, to form a zygote (sexual reproduction); *S, T*, a zygote dividing to form a group of schizonts. (Stages *H, K, L, N*, within epithelial cells.) All much enlarged.

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CURTLER: *A Short History of English Agriculture.* Oxford Univ. Press.
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FREAM: *Elements of Agriculture* (edited by Ainsworth-Davis). John Murray.
HALL: *Agriculture After the War.* John Murray.
HALL: *A Pilgrimage of British Farming.* John Murray.

HALL and RUSSELL: *Agriculture and Soils of Kent, Surrey, and Sussex* (Ministry of Agric.).
MACDONALD: *Dry Farming.* Werner Laurie.
PROTHERO: *English Farming Past and Present.* Longmans.
PUNNETT: *Mendelism.* Camb. Univ. Press.
SOMERVILLE: *Agriculture.* Williams & Norgate.
WRIGHTSON and NEWSHAM: *Theoretical and Practical Agriculture.* Crosby Lockwood.

III. CHEMISTRY

ADIE and WOOD: *Agricultural Chemistry.* Kegan Paul.
COUSINS: *Chemistry of the Garden.* Macmillan.
DODGSON and MURRAY: *Chemistry for Students of Agriculture.* Longmans.
WARINGTON: *Chemistry of the Farm.* Vinton & Co.
WOOD: *Chemistry of Crop Production.* Clive.

IV. SOILS AND MANURES

HALL: *Fertilisers and Manures.* John Murray.
HALL: *The Soil.* John Murray.
HOPKINS: *Soil Fertility and Permanent Agriculture.* Boston.
KING: *The Soil.* Macmillan.
MARR: *Agricultural Geology.* Methuen & Co.
RASTALL: *Agricultural Geology.* Camb. Univ. Press.
RUSSELL: *Soil Conditions and Plant Growth.* Longmans.
RUSSELL: *The Constitution of the Soil.* Camb. Univ. Press.
RUSSELL: *The Fertility of the Soil.* Camb. Univ. Press.
RUSSELL: *A Student's Book about Soils and Fertilisers.* Camb. Univ. Press.
WARINGTON: *Physical Properties of Soil.* Oxford Univ. Press.
WOODWARD: *Geology of Soils and Substrata.* Arnold.

V. ANIMALS

AUSTEN: *The House-Fly.* Brit. Museum (Nat. Hist.).
EALAND: *Insect Enemies.* Grant Richards.
FROHAWK: *Birds Beneficial to Agriculture.* Brit. Museum (Nat. Hist.).
Guides to the Horse Family and to Domesticated Animals (other than Horses). Brit. Museum (Nat. Hist.).
HINTON: *Rats and Mice as Enemies of Mankind.* Brit. Museum (Nat. Hist.).
HIRST: *Arachnida and Myriopoda Injurious to Man.* Brit. Museum (Nat. Hist.).
ORMEROD: *Manual of Injurious Insects.* Simpkin & Marshall.
RITZEMA BOS: *Agricultural Zoology* (translated by Ainsworth-Davis). Methuen & Co.
SOMERVILLE: *Farm and Garden Insects.* Macmillan.
THEOBALD: *Agricultural Zoology.* Blackwood.
THEOBALD: *Insect Life.* Methuen & Co.
WILSON: *The Evolution of British Cattle.* Vinton & Co.
WOOD and MARSHALL: *Physiology of Farm Animals.* Camb. Univ. Press.

VI. PLANTS (INCLUDING BACTERIA)

BIFFEN: *Plant Life in Farm and Garden.* Camb. Univ. Press.
BRENCHLEY: *Weeds of Farm Land.* Longmans.
BRUČK: *Plant Diseases* (translated by Ainsworth-Davis). Blackie & Son.
BUCHANAN: *Veterinary Bacteriology.* W. B. Saunders Company.
CLARK and FLETCHER: *Farm Weeds of Canada.* Canadian Dept. Agric.
CLARK and MALTER: *Fodder and Pasture Plants.* Canadian Dept. of Agric.
DE VRIES: *Plant Breeding.* Kegan Paul.
ERIKSSON: *Fungoid Diseases of Agricultural Plants* (translated by Molander). Baillière Tindall & Cox.
FREUDENREICH: *Dairy Bacteriology* (translated by Ainsworth-Davis). Methuen & Co.

HALL: *The Feeding of Crops and Stock.* John Murray.
H. C. LONG: *Common Weeds of the Farm and Garden.* John Murray.
MASSEE: *Diseases of Cultivated Plants and Trees.* Duckworth.
PETHERBRIDGE: *Common Fungus and Insect Foes.* Camb. Univ. Press.
PERCIVAL: *Agricultural Botany.* Duckworth.
PERCIVAL: *Agricultural Bacteriology.* Duckworth.
POTTER: *Agricultural Botany.* Methuen & Co.
SADLER: *Bacteria as Friends and Foes of the Dairy Farmer.* Methuen & Co.
SCOTT: *Clinical Bacteriology and Vaccine Therapy.* Baillière Tindall & Cox.
SUTTON: *Permanent and Temporary Pastures.* Sutton & Sons.

VII. PRACTICAL (See also I)

BOND: *Farm Implements and Machinery.* Benn Bros.
British Breeds of Live Stock. Ministry of Agric.
BROWN: *Encyclopædia of Poultry.* Waverley Book Co.
COWAN: *British Bee-Keeper's Guide-book.* Houlston & Sons.
DYER: *Fertilisers and Feeding Stuffs.* Crosby Lockwood.
FLATT: *Poultry Keeping.* Methuen & Co.
KELLNER: *The Scientific Feeding of Animals* (translated by Goodwin). Duckworth.
NEWSHAM: *Crops and Tillage.* Methuen & Co.
ORWIN: *Farm Accounts.* Camb. Univ. Press.
PORTER: *The Stockfeeder's Companion.* Gurney & Jackson.
SAKER: *Practical Dairying.* Methuen & Co.
TOD: *Hints on Feeding.* Bird Bros.
WALLACE: *Farm Livestock of Great Britain.* Oliver & Boyd.
WOOD: *The Feeding of Farm Animals.* Camb. Univ. Press.
WOODRUFF: *The Economics of Feeding Horses.* Baillière Tindall & Cox.

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